Foreword

National Oceanic and Atmospheric Administration

U.S. DEPARTMENT OF COMMERCE

NOAA Fisheries Service
Northeast Cooperative Research Partners Program

The National Marine Fisheries Service (NOAA Fisheries Service), Northeast Cooperative Research Partners Program (NCRPP) was initiated in 1999. The goals of this program are to enhance the data upon which fishery management decisions are made as well as to improve communication and collaboration among commercial fishery participants, scientists and fishery managers. NOAA Fisheries Service works in close collaboration with the New England Fishery Management Council's Research Steering Committee to set research priorities to meet management information needs.

Fishery management is, by nature, a multiple year endeavor which requires a time series of fishery dependent and independent information. Additionally, there are needs for immediate short-term biological, oceanographic, social, economic and habitat information to help resolve fishery management issues. Thus, the program established two avenues to pursue cooperative research through longer and short-term projects. First, short-term research projects are funded annually through competitive contracts. Second, three longer-term collaborative research projects were developed. These projects include: 1) a pilot study fleet (fishery dependent data); 2) a pilot industry based survey (fishery independent data); and 3) groundfish tagging (stock structure, movements and mixing, and biological data).

> First, a number of short-term research projects have been developed to work primarily on commercial fishing gear modifications, improve selectivity of catch on directed species, reduce bycatch, and study habitat reactions to mobile and fixed fishing gear.
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> Second, two cooperative research fleets have been established to collect detailed fishery dependent and independent information from commercial fishing vessels. The original concept, developed by the Canadians, referred to these as "sentinel fleets". In the New England groundfish setting it is more appropriate to consider two industry research fleets. A pilot industry-based survey fleet (fishery independent) and a pilot commercial study fleet (fishery dependent) have been developed.
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> Additionally, extensive tagging programs are being conducted on a number of groundfish species to collect information on migrations and movements of fish, identify localized or subregional stocks, and collect biological and demographic information on these species.

For further information on the Cooperative Research Partners Programs please contact:

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Improving the Selective Efficiency of Trawl Gear with Escape Windows and Visual Stimuli

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INTODUCTION

Recent management, industry and research initiatives have resulted in an improvement in overall biomass for Gulf of Maine groundfish stocks. However, bycatch and discard continues to be a significant driving force within the management process. Given recent legal action on the part of the coalition of Conservation organizations (Anon. 2001) and the response by NMFS and other parties it is clear that there is a compelling an urgent need to develop effective bycatch reduction strategies within the Gulf of Maine groundfish fisheries, particularly with regard to cod.

The favored management approach for reducing bycatch and discard is to reduce fishing effort through area closure or to increase mesh size, both of which have drastic effects on fishermen and coastal communities. Manomet Center for Conservation Sciences believes that alternative simple and cost-effective strategies are possible which do not require either area closure or the need for larger mesh sizes.

A widespread approach to bycatch reduction in otter trawl fisheries is to insert windows or escape panels in the extension and codends of trawl nets (Tschernij 1995; Glass 2000). Such devices have been adopted into fisheries legislation of the European communities, Canada, Australia and New Zealand. Escape windows are designed to provide large, open meshes for fish to pass through as they drop back along the extension and codend. However, as previously demonstrated (Glass et al. 1995) the natural behavior of fish is to avoid the meshes of netting around them. Only when fish were presented with an intense visual stimulus, the escapement rate of undersize fish from windows increased to almost 90%. The visual stimulus presented was a black canvas panel (1.5m in length) laced around the interior of the extension. This simple, inexpensive, bycatch reduction device has since been adopted into legislation in sectors of the Scottish North Sea. It is also under investigation in Gulf of Mexico trawl fisheries. The present project was designed to investigate the potential utility of this device, known as the black tunnel, in Northeastern U.S. fisheries.

In this study we investigated the effectiveness of two escape windows, both with and without an associated visual stimulus in the form of a black panel, in reducing bycatch and discard in Gulf of Maine groundfish fisheries. The escape windows were constructed with 7" hexagonal and 7" square mesh netting. Recent studies by Manomet Center for Conservation Sciences and commercial fishermen have shown hexagonal mesh to have substantially better selective efficiency than either diamond or square mesh. In addition, studies suggest hexagonal mesh may be the most appropriate mesh with which to construct escape windows (Manomet Center for Conservation Sciences and Engas and Lokkeborg pers comm.).

Project Goals and Objectives

The general and overall goals of the program were threefold:

- To help conserve fish stocks by reducing the bycatch and discard of non-target or undersized fish in Gulf of Maine otter trawl fisheries

- To provide high quality scientific information on the selective efficiency of two escape window codend configurations to allow better and more effective management of fish stocks.
- To encourage active participation of fishermen and the fishing industry in providing solutions to pressing problems within Northeastern US fisheries.

Our specific project objectives were:

- to investigate the effectiveness of two escape window codend configurations (with and without additional visual stimulus provided by the black tunnel) in reducing bycatch and discard of Gulf of Maine groundfish,
- to compare results with regulated mesh codends,
- to compare results of these experiments with most recent results of studies on selective efficiency of standard and novel codend arrangements,
- to quantify the behavioral responses of different fish species to the meshes of the escape window codend configurations and
- to make recommendations regarding implementation of such bycatch reduction devices into Gulf of Maine groundfish regulations.

METHODOLOGY

Gear

Novel escape windows (Figure 1) were constructed by commercial netmakers in New England. One escape window was constructed with 7" square mesh and the other with 7" hexagonal mesh. Each window measured 2m in length and extended around the entire upper and lower panel of the extension. A small mesh (4") diamond codend was attached to the aft of each window. Three plasticized canvas sheets of the appropriate dimensions were fitted with brass eyeholes around the leading and rear edges.

Experimental Protocol

Four window configurations were tested in this study:

- Square mesh (7") escape window
- Hexagonal mesh (7") escape window
- Square mesh (7") escape window with visual stimulus (black tunnel)
- Hexagonal mesh (7") escape window with visual stimulus (black tunnel)

The original project design called for testing the standard 61/2 " diamond mesh codend and the standard 6 1/2" square mesh codend. Due to time and vessel constraints the trials of these two codend configurations were not completed.

Trials were conducted at two different times of year, in the spring (May) and in the fall (October-December). This was done because preliminary studies conducted in the Gulf of Maine identified seasonal variation in the selective efficiency of codends (Glass et al. 2002). The experimental periods, May (spring) and October (fall, sampling extended through December), were chosen to allow for trials at a range of water temperature and conditions (see results for temperature data).

The original project design allowed for 3 different vessels to fish concurrently in separate areas of the Gulf of Maine during two different times of the calendar year, May and October. However, only one vessel, the F/V Christopher Andrew was able to participate in the first part of the project, in May 2004. Two vessels, the F/V Christopher Andrew and the F/V North Star, participated in the second part of the project. Due to availability of the vessels and weather conditions, the fall trials extended from October through December.

This project was originally split into two separate experimental portions. Experimental fishing permits were initially issued for the first set of experimental sea trials (spring trials) and PI's were required to submit requests for EFP's for the second set of sea trials (conducted in the fall). During the first stage vessels were permitted exemption from the DAS regulation. However, prior to the start of the second set of trials, a change in the DAS requirements occurred. No DAS exemption was permitted for the sea trials conducted in the fall. This change in policy led to the last minute cancellation of the third participating vessel.

Vessel Descriptions

The F/V Christopher Andrew is approximately a 60 ft length vessel. The F/V Christopher Andrew completed hauls east of Scituate MA in May and in October (Figure 2). The F/V North Star is approximately a 45 foot length vessel. It completed hauls east of Portland, ME in the fall (October-December) (Figure 2). The F/V North Star's net had a larger fishing circle (mouth) with 300 6 inch meshes around compared to the F/V Christopher Andrew's net, which had only 105 6 inch meshes around. Table 1. displays the trawl gear characteristics for the F/V Christopher Andrew and the F/V North Star.

Sampling protocol

The four mesh window configurations were tested through day trips, with each day testing either the 7"Hex or the 7"Sq window. The A-B-B-A protocol was used for the addition of the back tunnel visual stimulus to the window configuration. Each tow was approximately 20 minutes. A minimum of 30 valid hauls per experimental configuration and a minimum of 15 valid hauls with the standard (or control) codends were the standing requirements for this project. A total of 31-33 valid hauls were completed for each of the four window configurations.

All fish retained by the codend of each haul were separated by species and weighed and their disposition recorded. In addition to the weights, commercially important fish, were counted and measured for length frequency. Undersized fish were returned to the sea as quickly as possible and no undersized fish was retained on board. Full NMFS sea sampling protocols were employed and all sampling was conducted by observers certified to NMFS standards. Data was collected on NMFS standard sea sampling forms and data will be made available to NMFS (on paper and in electronic format) at the conclusion of the project.

Determination of selectivity parameters

In order to estimate selectivity parameters, it is necessary to use covered codends (see Anon, 1991, 1996). The original project design called for the use of a small-mesh cover (3" diamond mesh) to be attached to the exterior of the codend and experimental escape window and held away from the meshes of the net using two circular plastic tubes (2" inside diameter). All fish passing through the escape window would be retained within the cover. A small mesh codend will also be used to retain fish within the codend that pass the window without escaping. Use of such a technique allows the absolute selective efficiency of each window to be determined while minimizing both the duration and number of tows required. Manomet Center for Conservation Sciences has employed this technique successfully in a number of studies in the Gulf of Maine and on a number of vessels included in this proposal (see Glass, 2000, 2001a, 2001b, Glass et al, 2002). In addition, full-scale flume tank trials have allowed this design to be studied and perfected.

However, in the project reported here discussions between all project partners determined that it would not be feasible to use a covered codend technique, despite the willingness of the PI's to attempt this during development of the proposal. A number of separate covers would have been necessary, one to capture the fish passing through the codend, and the other to capture the fish passing through the window. The cover for the window would have been required to encircle the entire net, as the window spans the circumference of the net and a second would have been required to surround the entire codend. Further, one cover would have had to be within the other. In order to prevent one cover interfering with rigging and operation of the other cover (and escapement from the codend) it was collectively determined that such a configuration would not only be extremely large and cumbersome but it would be impracticable in commercial fishing operations. A collective decision was therefore made to modify the experimental approach and to focus on comparative fishing techniques using a small mesh (4" diamond) codend to retain all fish that passed the window without escaping.

Behavioral observations

Where practicable, underwater video cameras were placed in the net to determine that the net and escape windows were rigged and fishing correctly, and to record reaction behavior of fish species to the meshes of the escape windows. Footage was collected for both 7" hex and 7" square windows, with and without the black tunnel. The overall quality of the images is generally poor due to the lack of ambient underwater illumination (artificial lighting cannot be used without affecting the natural behavior of the fish) and poor underwater visibility. However, sufficient footage was obtained to enable the investigators to determine that the experimental net was fishing correctly and to observe that escape responses to the open meshes of the escape window did in fact occur.

Data Analysis

The data was analyzed to determine both the effect of the window mesh (hex and sq) and the presence of the visual stimulus (black tunnel) at reducing the bycatch and discard of undersize fish. The difference in catch among the four window configurations, 7" Hex window, 7"Hex window with black tunnel, 7" Sq window and 7" Sq window with black tunnel, was compared in terms of catch per unit effort (CPUE) using the nonparametric Kruskal-Wallis analysis of variance. The catch was compared in terms of CPUE (number/weight of fish caught per hour fished) in order to remove the variation due to differences in time fished per haul. The nonparametric analysis of variance was used because the data does not meet the assumptions of normality or homogeneity of variances needed for the parametric analysis of variance. The Kruskal-Wallis test examines the null hypothesis that there are no differences among the groups (experimental window configurations), through an examination of the variances by ranks. When the null hypothesis (that all groups are the same) of the Kruskal-Wallis test was rejected, nonparametric multiple comparisons were performed to determine where the significant difference among the groups occurred. The nonparametric multiple comparisons test examines differences between the groups using group rank sums.

Data was analyzed for total caught, kept, discard and discard of undersize fish. The following seven different disposition codes/reason were recorded during this study: 001 no market or no reason specified, 012 regulations prohibit retention, too small, 013 regulations prohibit retention, too large, 014 regulations prohibit retention, quota filled, 023 regulations prohibit retention, soft shelled, 024 regulations prohibit retention, with eggs, 025 regulations prohibit any retention (no permit), 100 Kept. The total kept catch was obtained by the addition of fish with disposition codes 014 and 100. Although fish with the 014 disposition code were not retained, they were discarded due to the quota being filled, and were actually fish of landable size. The total discard refers to all fish with the disposition codes: 001, 012, 013, 023, 024, and 025. The discard of undersize fish refers to the commercially viable species with disposition code 012.

Preliminary studies conducted in the Gulf of Maine (Glass et al. 2002) identified seasonal variation in selective efficiency of codends. Due to this finding, the data was analyzed separately according to season sampled: spring (May sampling) and fall (October-December sampling). In addition, the vessel used to conduct the trawl influences the catch size and therefore may influence the fishing efficiency of the window configurations. In this study, only two vessels, the F/V Christopher Andrew and the F/V North Star sampled two different areas in the Gulf of Maine. The F/V Christopher Andrew sampled east of Scituate, MA, and the F/V North Star sampled east of Portland, Me. In the spring only the F/V Christopher Andrew conducted the survey. In the fall both vessels conducted tows, with the majority of tows completed by the F/V North Star (Table 2). To avoid confounding any possible seasonal and vessel effects, the differences in catch among the four window configurations were analyzed by vessel for each season before being pooled and analyzed together.

RESULTS

Trip and Haul Descriptions

In May 2004 the F/V Christopher Andrew undertook 8 day trips east of Scituate, MA testing both windows with and without addition of the black tunnel visual stimulus (Table 2-3, Figure 2). Of a total of 41 hauls, 10 were performed with the 7" hex window, 10 were performed with the 7" hex mesh window and the black tunnel, 11 were performed with the 7" square window and 10 were performed with the 7" hex mesh window and the black tunnel.

In October 2004 the F/V Christopher Andrew undertook 4 day trips east of Scituate, MA testing both windows with and without the addition of the black tunnel visual stimulus (Table 2-3, Figure 2). The F/V Christopher Andrew completed 25 hauls, 6 were performed with the 7" hex window, 6 were performed with the 7" hex window and black tunnel, 7 were performed with the 7" square window and 6 were performed with the 7" square window with the black tunnel. One haul, performed with the 7" square window with the tunnel off, was not valid (it lasted 4 minutes) and was therefore removed from further analyses. In October 2004 the F/V Christopher Andrew completed 24 valid hauls, 6 performed for each window configuration.

The F/V North Star undertook 10 day trips east of Portland, ME beginning in October and extending through December (due to vessel and weather constraints) testing both windows with and without the addition of the black tunnel visual stimulus (Table 2-3, Figure 2). The F/V North Star completed a total of 61 hauls, 15 were performed with the 7" hex window, 15 were performed with the 7" hex window and black tunnel, 15 were performed with the 7" square window and 16 were performed with the 7" square window with black tunnel.

In total 126 valid hauls were conducted, 31 7" hex window, 31 7" hex window + black tunnel, 33 7" sq window, and 31 7" sq window + black tunnel (Table 2-3, Figure 2). Two vessels were used to conduct the study in two areas in the Gulf of Maine. The F/V Christopher Andrew surveyed east of Scituate, MA and the F/V North Star surveyed east of Portland, Me. The surveys were conducted in the spring 2004 (May) and in the Fall 2004 (October-December)

Tow length ranged from 15 to 34 minutes, with an average tow length of 22 minutes (Table 3, 4). Due to this variation in tow length, the catch per haul was analyzed in terms of catch per unit effort (pounds or number of individuals/hour fished). The F/V Christopher Andrew's average tow speed (2.8) was slightly higher than the F/V North Star's (2.4). Bottom temperatures varied by season. The average bottom temperature was around 3 to 4 degrees C in the spring and 7 to 8 degrees C in the fall (Figure 3).

Over 34 individual species were observed in the experiment (Table 5-6). The species were grouped into 7 categories: flatfish (commercially important: Dab (American Plaice), Witch Flounder (Grey Sole), Winter Flounder, Yellowtail Flounder, and Halibut), roundfish (Cod, Haddock, White Hake, and Pollock), monkfish, spiny dogfish, skates, invertebrates, and other. The other category is comprised of species that composed 1% or less of the total catch (Table 7-8).

Vessel Differences

In the fall, the F/V Christopher Andrew caught statistically significantly more fish than the F/V North Star for each window configuration (Table 4, Figure 4). In addition, the F/V Christopher Andrew discarded and kept statistically significantly more fish than the F/V North Star. Despite catching and keeping significantly less fish, the F/V North Star discarded significantly more undersize fish than the F/V Christopher Andrew. This indicates that the nets employed by the F/V Christopher Andrew may allow more undersize fish to escape through the window configurations.

Due to the differences observed in the amount of fish caught between the vessels it is possible the window configurations could affect the catch differently for each vessel. Therefore it is necessary to explore possible differences in window mesh (hexagonal or square) and presence/absence of visual stimulus (black tunnel) individually for each vessel.

Seasonal Differences:

Differences in the quantity of fish caught, kept and discarded were observed between the spring and the fall (for hauls conducted by the F/V Christopher Andrew only), in a comparison between the each window configuration (Table 4, Figure 4). There was no statistical difference in the total catch or discarded catch by weight (CPUE) between the spring and fall for the 7" hex window configuration. The kept catch and discard of undersize fish for the 7" hex window configurations were greater in the spring, with the difference statistically significant for the 7" hex window with the black tunnel off (Mann-Whitney $p = 0.039$ and 0.039 respectively) and was approaching significance for the 7" hex window with the black tunnel on (Mann-Whitney $p= 0.083$ and 0.104 respectively).

Both the 7" sq window configurations with the tunnel off and on had statistically significantly higher total catches in the fall than in the spring (Mann-Whitney $p= 0.002$ and 0.023 respectively) (Figure 4). The amount of total fish discarded was also significantly higher in the fall for both the 7" hex window with the tunnel off and with the tunnel on (Mann-Whitney $p= 0.001$ and 0.083 respectively). The amount of fish kept was larger in the fall, with the difference significant for the 7" sq window with the tunnel on (Mann-Whitney $p= 0.017$). There was no significant difference in the amount of undersize fish discarded by the 7" sq windows between the fall and the spring. These results suggest that the 7" sq mesh windows allow more undersize fish to escape in the fall. The results could also be due to a difference in the community of fish sampled between the seasons, rather than an increase in escapement of undersize fish.

The community of fish caught in the spring and fall differed (Table 6-8). For example, Haddock, Pollock, Winter Flounder, and Yellowtail Flounder were more abundant in the spring and virtually absent in the hauls conducted in the fall, while Monkfish and Witch Flounder (Grey Sole) were more abundant in the fall. This variation in the composition of fish may influence the effectiveness of escape windows at reducing the bycatch and discard of undersize fish, as each species or the community of fish as a whole, may react differently to the mesh and presence of the visual stimulus.

Analysis of the window configurations by haul weight and number of individuals

Due to the differences observed in the catch for each window configuration between the vessels and between the seasons, the differences among the window configurations were analyzed by vessel for each season, before being pooled and analyzed together to determine if there was an overall affect of the window configuration on reducing the bycatch and discard of undersize fish.

In the spring the F/V Christopher Andrew conducted hauls east of Scituate, MA. In general, the hexagonal mesh windows, with the tunnel on and off, caught more fish, kept more fish and discarded more fish, in terms of weight and number, than the square window configurations (with the tunnel on and off) (Table 4, 9, Figure 5-6). Differences in catch weight were only significant for the kept catch (Kruskal-Wallis p=0.026) (Table 9). The 7" hex window with the black tunnel on kept significantly more fish than the 7" square window with the black tunnel on. The difference among the window configurations was approaching significance for the discard of undersize fish (Kruskal-Wallis p=0.063). The multiple comparison analysis indicates this difference can mainly be attributed to the 7" hex window with the tunnel off discarding more fish than the 7" square window with the tunnel on.

Significant differences were also observed for the number of fish kept in the spring (Kruskal-Wallis p=0.014) (note that the number of fish refers only to commercially important fish measured for length frequency analyses) (Table 4, Figure 6). The significant difference observed were due to the 7" hex window with the black tunnel off keeping significantly more fish than the 7" sq window with the black tunnel on. The difference among the window configurations for the total catch by number of fish was approaching significance (Kruskal-Wallis p=0.063) (Table 4, 9, Figure 6). This can be attributed to the difference between the nets with the 7" hex windows discarding more than the 7" sq window with the black tunnel on.

In the fall, the F/V Christopher Andrew conducted 6 hauls per window configuration east of Scituate MA, and the F/V North Star conducted 15-16 hauls per window configuration east of Portland ME. Statistical differences among the window configurations were observed only for hauls conducted by the F/V Christopher Andrew (Table 9).

In general, on the F/V Christopher Andrew the 7" sq mesh window configurations caught, kept and discarded more fish by than the 7" hex window configurations (Table 4, 9, Figure 5, 6). No difference was observed in the amount of undersize fish discarded between the sq and hex mesh window configurations. This finding is the opposite of what was observed for hauls conducted by the F/V Christopher Andrew in the spring, where the hex mesh windows caught more fish than the sq mesh windows. The difference among the window configurations was significant for the total fish caught by weight (p=.051) and kept (p=.034) (Table 9). The multiple comparison analysis indicated the difference among the window configurations for the total fish caught is mainly due to 7" sq mesh with the black tunnel off catching more than the 7 hex window with the black tunnel off. The difference among the window configurations for the kept fish is mainly due to the 7" sq mesh window with the black tunnel on keeping more than the 7" hex mesh window with the black tunnel on.

Statistically significant differences were also observed for the number of fish in terms of CPUE among the window configurations for the hauls conducted on the F/V Christopher Andrew in the fall (Table 4, 9, Figure 5). The number of fish discarded was significantly different (p=0.005), with the 7" sq window with the tunnel off discarding more fish than the 7" hex with the tunnel on. The difference among the window configurations was also approaching significance for the total catch (p=0.093), with the 7" square windows catching more than the 7' hex windows.

No statistical differences were observed among the window configurations for hauls conducted by the F/V North Star in the fall (Table 9). In addition, when all hauls conducted in the fall were pooled, no significant differences were observed. Although not significant, the square mesh window configurations caught more than the hex mesh window configurations (Table 4, Figure 5-6).

Overall, no significant differences for the total, kept, discard, and discard of undersize fish were found among the four window configurations when all data was pooled together (Table 9). Further, no consistent trend was observed for the presence/absence of the visual stimulus, or the between the two meshes (hexagonal and square) (Table 4, Figure 5-6).

In addition, no significant differences were observed among the window configurations for the proportion of the catch that was kept and discarded (total discard, and discard of undersize fish) for either vessel, in either season, or for all data pooled (Figure 7). This indicates the differences observed among the window configurations for the weight and number of fish caught, kept and discarded were likely due to overall differences in the total amount of fish caught, rather than differences as to the effectiveness of the escape windows at reducing the bycatch and discard of undersize fish.

The catch comparison of haul number and weight indicates that, overall, the visual stimulus provided by the black tunnel did not reduce the bycatch or aid in the escapement for undersize fish, for either the 7 hex window or the 7 sq window. Further, the shape of the mesh, hexagonal or square does not appear to consistently or significantly affect the amount kept and discarded. Neither mesh appeared to increase the escape of bycatch and undersize fish through the windows.

Analysis of the window configurations by catch composition

Few differences were observed in the composition of the catch among the window configurations in either season, on either vessel, or when all hauls were pooled together (Table 7, Figure 8). The type of mesh and the presence/absence of the black tunnel do not appear to reduce the bycatch or discard of undersize fishes consistently between the vessels and seasons for any type/category of fish.

Differences in the catch (weight and number of individuals) among the window configurations were analyzed for each category of fish with the Kruskal-Wallis non-parametric analysis of variance (Table 10). Significant differences were observed only for hauls conducted in the fall for invertebrates, monkfish, and skates. Note that differences for monkfish would be unlikely in the spring, as monkfish were virtually absent from the hauls conducted in the spring.

Monkfish

In the fall, for hauls conducted by the F/V Christopher Andrew, the nets with the 7" sq windows caught and kept more monkfish than the nets with the 7" hex windows (Table 7). The total and kept catch differed significantly among the window configurations (Kruskal-Wallis p= 0.007 and 0.007 respectively) (Table 10) with the multiple comparison analysis indicating the difference was mainly due to the 7" sq window with the tunnel on catching and keeping significantly more monkfish than the 7" hex window with the tunnel on. No difference was observed among the window configurations for the discard of monkfish.

Differences in CPUE among the window configurations were also significant for the number of monkfish caught, kept, and discarded (all were discarded for being undersized) for the F/V Christopher Andrew in the fall (Kruskal-Wallis $p = 0.002$, 0.002, and 0.039 respectively) (Table 10). The 7" sq window configurations caught, kept and discarded more individual monkfish than the 7" square windows (Table 7). The statistical difference among the number of monkish is attributed to the 7" sq with the tunnel off catching, keeping and discarding more fish than the 7" hex with the tunnel on.

No differences were observed in the total, kept and discarded catch (CPUE) of monkfish for hauls conducted by the F/V North Star in the fall (Table 7, 10). When hauls conducted by both vessels were pooled, the difference in the total and kept catch by weight, and the kept catch by number remained significant, with the multiple comparison analysis indicating the difference was due to the 7" sq window with the tunnel off catching and keeping more monkfish than the 7" hex window with the tunnel on.

Overall there were no statistical differences between the populations (length frequency distributions) sampled by the hex and sq mesh windows (Figure 9). The populations sampled by the nets with the 7" sq mesh windows with the tunnel on differed statistically significantly from the populations sampled by the nets with the 7" sq mesh with the black tunnel off (Figure 10). A larger portion of the population sampled by the 7" sq window with the tunnel off was undersize fish. No differences were observed in the populations of fish by the nets with the 7" hex windows with the tunnels on and off.

The results from the F/V Christopher Andrew in the fall may indicate that the sq mesh allows more undersize monkfish to escape through the windows than the hex mesh. The differences observed in the LFDs suggest the presence of the black tunnel may increase the escape of undersize fish, at least for the sq mesh window configurations.

Skates

Differences were observed among the window configurations for the amount of skates caught and discarded (note that no skates were kept) for hauls conducted by the F/V North Star in the fall (Table 10). The 7" hex window configurations caught more skates than the 7" square window configurations (Table 7). The multiple comparison analysis indicates the statistical difference among the window configurations can be attributed to the 7" sq window with the black tunnel on catching and discarding more skates than the 7" hex window with the black tunnel on. This indicates that the square mesh may reduce the bycatch of skates better than the hexagonal mesh. The presence or absence of the black tunnel visual stimulus does not appear to affect the amount of skates caught.

Invertebrates

Significant differences were observed among the window configurations for the amount of invertebrates, which include crabs and lobster, caught and discarded, for hauls conducted in the fall by the F/V North Star (Table 10). Note that no invertebrates (i.e. lobsters) were kept due to regulations. The significant differences were also observed when all hauls from both seasons and vessels were pooled. The nets 7" hex mesh windows caught more invetertebrates than the nets with the 7" sq mesh windows (Table 7). The multiple comparison analysis indicates the statistical difference observed among the window configurations is attributed to the nets with the 7" hex window with the black tunnel off catching and discarding statistically significantly more than the 7" sq window with the black tunnel on.

No differences were observed among the window configurations for the amount of invertebrates for hauls conducted in the spring or on the F/V Christopher Andrew in the fall (Table 10). This is not unexpected result as very few invertebrates were caught in these hauls (Table 7).

The statistical differences observed among the window configurations indicate the square mesh windows may reduce the catch/bycatch of invertebrates in comparison to the hex mesh windows. The presence/absence of the visual stimulus does not appear to affect the catch and discard of invertebrates for the mesh types.

Roundfish

In general, roundfish were more abundant in the spring. They were also more abundant in hauls conducted by the F/V Christopher Andrew in the fall, in comparison to hauls conducted by the F/V North Star (Table 7). Haddock were abundant in the spring and virtually absent in the fall (Table 8). Cod was present in the catch in both the spring and the fall, and made up the majority of the roundfish catch in the fall (Table 8).

In the spring, the 7" hex window configurations caught, kept and discarded more roundfish than the 7" square window configurations (Table 7). The difference among the window configurations for the amount of roundfish discarded was approaching significance for the hauls conducted in the spring by the F/V Christopher Andrew, in terms of weight and number ($p = 0.10$ and 0.085 respectively) (Table 10). The multiple comparison analysis indicates this difference is mainly due to the 7" hex window with the tunnel off discarding more than the 7" sq with the tunnel on. These differences observed in the spring for the F/V Christopher Andrew indicate the the 7" square mesh window may allow more undersize roundfish to escape than the 7" hex mesh windows.

In the fall, no significant differences were observed for the catch of roundfish in hauls conducted by the F/V Christopher Andrew (Table 10). Although not significant, the 7" sq window configurations caught more roundifsh than the 7" hex window configurations, the opposite of what was observed in the spring (Table 7).

Statistical differences were observed among the window configurations for hauls conducted in the fall by the F/V North Star (Table 10). The amount of roundfish discarded by weight (CPUE) differed significantly (Kruskal-Wallis $p=0.045$), with the multiple comparison analysis indicating 7" hexagonal mesh with the black tunnel off discarded statistically significantly more than 7" hexagonal mesh with the black tunnel on. This difference appears to be attributed to large catches of white hake being discarded (Table 7, 8). Although there is no legal size limits for White Hake the discard was likely due to the fish being too small.

No consistent trend was observed for the amount of roundfish caught, kept and discarded with the presence and absence of the addition of the visual stimulus. In addition, no consistent trend was observed between the seasons and vessels, for the effectiveness of the type of mesh.

Although the results from the spring may indicate the 7" square mesh windows may allow more undersize roundfish to escape than the 7" hex mesh windows. Therefore, the use of square mesh windows may reduce the bycatch and discard of roundfish.

Flatfish

In general, flatfish were more abundant in the catch in the spring (Table 7). In addition, the community of flatfish differed between seasons, with Winter Flounder, and Yellowtail Flounder more abundant in the spring and Witch Flounder (Grey Sole) more abundant in the fall (Table 8). In the fall, flatfish were more abundant in the hauls conducted by the F/V Christopher Andrew (Table 7).

In the spring, no statistical differences were observed among the window configurations for either the weight or number of flatfish caught, kept and discarded (Table 10). The nets with the hex mesh windows tended to catch, keep and discard more flatfish than the nets with the square mesh windows (Table 7).

In the fall, statistical differences were observed in the catch of flatfish among the window for the hauls conducted by the F/V Christopher Andrew (Table 10). The number of flatfish discarded differed significantly among the window configurations (Kruskal-Wallis $p=0.024$). This difference is attributed to the 7 sq mesh window with the tunnel off discarding significantly more flatfish than the 7" hex window with the tunnel on. On average, the sq mesh windows discarded more flatfish than the hex mesh windows (Table 7). No differences were observed among the window configurations for the number of total flatfish caught and kept.

The results observed indicate that the hex mesh window may be better at allowing undersize flatfish to escape than the square mesh windows (in the fall). The use of hexagonal mesh escape windows may decrease the bycatch and discard of undersize fish, while maintaining the catch of targeted sizes. The presence of the visual stimulus does not appear to affect the escape of undersize flatfish.

Analysis of the window configurations for commercially important species

The results from the analyses of roundfish and flatfish indicate that the window configurations may be affecting individual species differently. In addition, the results suggest the populations (size distributions) of fish sampled may differ between the seasons and vessels. Further analyses were completed to determine if the type of mesh and presence/absence of the additional visual stimulus (black tunnel) affected the catch and release of the commercially important roundfish and flatfish. Statistical differences were found among the window configurations for the amount of cod, hake, dab (American Plaice), winter flounder (blackback), and witch flounder (grey sole) (Table 11). No statistical differences were observed for yellowtail flounder, pollock, halibut and haddock. This lack of statistical differences for pollock, halibut, and haddock is likely due to the small and infrequent catches of these fish (Table 6, 8).

Cod

In the spring, on average the hexagonal mesh window nets caught, kept and discarded more cod than the nets with the square mesh windows (Table 8). The difference among the window configurations was statistically significant for the total and kept catch (Kruskal-Wallis p= 0.007 and 0.0299 respectively) (Table 11). In addition, the discard of cod was approaching significance (Kruskal-Wallis p=0.079).

The multiple comparison analysis indicates the difference among the window configurations for the total cod caught is due to the 7" hex with the tunnel off and the 7" hex with the tunnel on catching significantly more fish than the 7" sq window with the tunnel on. The difference among the window configurations for the kept cod is mainly due to the 7" hex with the tunnel on keeping more than the 7" sq with the tunnel off and the 7" sq with the tunnel on. The multiple comparison analysis indicates the difference in the discard observed among the window configurations was due to the 7" hex window with the tunnel off and the 7" hex window with the tunnel on discarding more fish than the 7" sq window with the tunnel on.

The length frequency distribution analyses between the square and hex mesh (both with the black tunnel off) indicate the populations sampled differed (two-sample K-S p=0.028) (Figure 9). The cod caught by the hexagonal mesh had a larger size distribution, containing more small and large fish than the population of cod caught by the nets with the square mesh windows. No difference was observed in the length frequency analyses between the presence and absence of the black tunnel for either the hex or the sq mesh windows (Figure 10).

The differences observed in the spring appear to be due to the nets with the hexagonal mesh windows catching, overall, more cod than the nets with the square mesh windows (Table 8, 11). Neither mesh type appears to decrease the discard of undersize cod (i.e. allow more undersize fish to escape through the mesh window). The results indicate the square mesh could be allowing both undersize and legal cod to escape through the windows better than the hexagonal mesh. The presence or absence of the additional visual stimulus does not appear to affect the release of cod through the escape windows.

No significant differences were observed among the window configurations for cod in the fall (Table 11). No differences were observed in the populations of cod (length frequency distributions) between the mesh types or presence/absence of the visual stimulus for the fall (Figure 9-10).

The populations of cod sampled differs between the spring and fall (Figure 11). The length frequency analysis indicates the population of cod caught in the fall contained more small fish and less large fish, than the population of cod caught in the spring (in a comparison between hauls conducted by each window configuration by the F/V Christopher Andrew in the spring and fall).

In the fall the F/V North Star, on average, caught less cod than the F/V Christopher Andrew (Table 8). The populations of cod sampled by each vessel also differed (Figure 12). The F/V North Star caught mainly legal (large) sized cod. The population of cod caught by the F/V Christopher Andrew had a larger length frequency distribution, containing a large portion of undersize (small) fish.

Dab

No statistical differences were observed among the window configurations for Dab caught in hauls by the F/V Christopher Andrew in the spring (Table 11). In addition, no clear trend in the data was observed for catches between mesh types or with the presence or absence of the visual stimulus black tunnel (Table 8).

In the fall, no statistical differences in the amount of dab caught, kept or discarded were observed among the window configurations for hauls conducted by the F/V North Star. Statistical differences among the window configurations were observed for hauls conducted by the F/V Christopher Andrew in the fall. In terms of both weight and number of individuals the amount of total dab caught (Kruskal-Wallis $p= 0.024$ by weight and $p=0.003$ by number) and discarded (Kruskal-Wallis $p= 0.018$ by weight and p= 005) differed significantly among the window configurations (Table 11). In general the nets with the 7" sq mesh windows caught and discarded more dabs than the nets with the 7" hex mesh windows (Table 8). The net with the 7" sq window with the tunnel of caught and discarded significantly more dabs than the 7" hex window with the tunnel on.

The length frequency analyses between the two mesh types (for hauls conducted by the F/V Christopher Andrew) indicates that a larger portion of the dabs caught the nets with the 7" sq mesh were smaller than those caught by the nets with the 7" hex mesh (two-sample K-S $p= 0.000$ for the comparison between mesh types with the tunnel off) (Figure 9). No differences were observed for the populations of fish caught with or without the black tunnel, according to the LFDs (Figure 10).

The same difference in populations sampled between the nets with the 7" hex mesh windows were observed in the spring and in the fall on the F/V North Star. The difference was statistically significant in most of the comparisons (Figure 9). No differences were observed in the LFDs for dabs caught with or without the addition of the black tunnel visual stimulus for either the hex or sq mesh windows in the spring, in the fall by the F/V North Star, or overall (Figure 9).

The populations of dabs caught differed between the seasons and vessels (Figure 11-12). The population of dab caught in the fall was smaller in length than that in the spring. A larger portion of the catch in the fall was of undersized dabs. Additionally, the dab caught by the F/V Christopher Andrew tended to be smaller than those caught by the F/V North Star. Overall, in the fall the majority of dabs caught by either vessel were undersize. The lack of statistical differences observed in the spring, and in the fall on the F/V North Star, could be due to the population of dab being mainly larger fish.

The results indicate that the hex mesh may allow more undersize dabs to escape than sq mesh, while the presence of the additional visual stimulus does not influence the escape of dabs.

Winter Flounder

Winter flounder were more abundant in the catches in the spring (Table 8). Further, the LFDs indicate a larger portion of the population of winter flounder caught in the spring were smaller and of sub-legal size (Figure 12).

Winter flounder were more abundant in the catches conducted by the F/V Christopher Andrew in the fall, in comparison to the F/V North Star (Table 8). As only a few fish were caught in the hauls conducted by the F/V North Star, no trends could be observed between the populations (LFDs) sampled by each vessel (Figure 11).

In the spring, differences in weight (CPUE) caught among the window configurations were approaching significance for the discard (Kruskal-Wallis p=0.077) and total catch (Kruskal-Wallis p=0.087) (Table 11). In general, the nets with the hex mesh windows caught, kept and discarded more than the nets with the sq mesh windows (Table 8).

Statistical differences were found between the length frequency distributions of winter flounder caught by the nets with hex and sq windows (Figure 9). A larger portion of the population of flounder sampled by the nets with the hex mesh was smaller in length. No statistical differences were found in between the populations (LFDs) for the presence and absence of the additional visual stimulus (Figure 10).
The differences observed among the nets for the total and kept catches and in the LFDs may indicate the use of square mesh windows decreases the discard of undersize winter flounder.

In the fall, for hauls conducted by the F/V Christopher Andrew, the nets with the hexagonal mesh window caught, kept and discarded more flounder by weight (CPUE) than the nets with the sq mesh window (Table 8). The difference among the window configurations was significant in all cases (Kruskal-Wallis p= 0.024, 0.048, 0.049 respectively) (Table 11). The difference was also significant for the number of fish discarded (CPUE) (Kruskal-Wallis p=0.023).

No statistical differences were observed for hauls conducted by the F/V North Star. As winter flounder catches were small and infrequent for in the hauls conducted by the F/V North Star, the lack of statistical differences is an expected result (Table 6, 8). Overall, when all hauls conducted for both seasons and vessels were pooled, no statistical differences were observed.

Overall, the results indicate the square mesh allows more winter flounder, both undersize and legal size, to escape through the window. The presence of the additional visual stimulus does not appear to affect the escape of winter flounder.

Witch flounder (grey sole)
Witch flounder were more abundant in the hauls conducted in the fall (Table 8). No statistical differences among the window configurations were observed for the amount (weight and number) of grey soles caught in the spring (Table 11). This is an expected result, as very few grey soles were caught in the spring. Significant differences in the catch (CPUE) were observed among the window configurations for hauls conducted in the fall by the F/V Christopher Andrew. Overall, when hauls form both seasons and vessels were pooled, no significant differences were observed in the weight and number (CPUE) of grey soles caught, kept and discarded.

In the fall for hauls conducted by the F/V Christopher Andrew, statistical differences were observed for the total weight caught, kept, discarded and discarded due to being undersized

(Kruskal-Wallis p=0.005, 0.005, 0.044, and 0.005 respectively) (Table 11). The nets with the sq mesh window caught, kept and discarded more grey sole than the nets with the hex mesh windows (Table 8). The multiple comparison analysis indicates the statistically significant differences observed among the window configurations in attributed to the 7" sq window with the tunnel on catching, keeping and discarding significantly more than the 7" hex window with the tunnel on. No difference was observed in the length frequency distributions between the mesh types (Figure 9), or presence/absence of the visual stimulus black tunnel (Figure 10). These results indicate the hexagonal mesh window allows more grey sole, of all sizes, to escape.

Differences were observed in the populations sampled by the F/V Christopher Andrew and the F/V North Star in the fall (Figure 12). The LFD indicates a larger portion of the population of grey sole sampled by the F/V North Star was undersized (i.e. the population of fish was smaller in size than that sampled by the F/V North Star).

Differences were observed in the LFDs between the window mesh types for all hauls conducted in the fall (when hauls from both vessels were pooled) (Figure 11). Larger portion of the population caught by the nets with the 7" square mesh windows were of landable size. The difference was statistically significant (two sample K-S test p=0.001 for windows with the tunnel off and 0.000 for windows with the tunnel on).

The analyses indicate the nets with the square mesh windows retain more grey sole than the nets with the hex mesh windows. The use of hexagonal mesh windows appears to decrease the discard of grey sole, however it appears a sizable portion of the marketable fish are missed with the use of the hexagonal mesh windows.

White Hake
Statistical differences were observed for the weight of hake discarded by the F/V North Star in the fall (Kruskal-Wallis 0.047) (Table 11). The difference appears to be caused by a large portion of hake discarded for hauls conducted by the 7"hex window with the tunnel off (Table 6, 8). Although there are no legal limits to the size of white hake, the discarded hake were likely considered too small to be profitable. Therefore, the difference may suggest either window mesh (hex or sq) is better at allowing undersized hake to escape.

DISCUSSION

The use of escape windows have been successful at reducing the bycatch and discard of undersize fish, and has been employed as a management measure in other countries including Canada. In this study, unfortunately no hauls with standard net configurations were done. Therefore, the overall effectiveness of the escape window could not be evaluated. It is possible, and highly likely that the use of nets with the escape windows reduced the overall discard of undersize fish through allowing their escape through the window mesh.

This study tested four different configurations of escape window inserted into the extension and codends of trawl nets. Two different mesh types for the windows, 7" hex and 7" sq, were tested, both with and without the addition of the black tunnel visual stimulus. While this study could not determine if the escape windows were successful in reducing the bycatch while maintaining the catch of targeted species in comparison to standard nets currently used in the groundfish fishery, a comparative analysis between the four window configurations could provide information on which mesh type worked the best and if the addition of the black tunnel increased the escape rate of fish.

Seasonal Differences

The four window configurations were tested in the spring and fall, as previous studies identified seasonal variation in the in the selective efficiency of codends in the Gulf of Maine (Glass et al. 2002). Seasonal differences in water conditions (temperature) were observed in this study. The bottom temperatures in the spring were colder, averaging around 3-4, than the fall, when bottom temperatures were around 7-8 degrees. This difference in bottom temperatures indicates further difference in the water conditions. In spring it appears that the thermocline was well defined. In the fall the water was likely more turbulent and mixed. The difference in temperatures possibly indicates differences in visibility in the water column. With more mixed and turbulent conditions in the fall, visibility may be lowered. The difference in visibility could affect the escape of fish through the windows, and the effect of the black tunnel additional visual stimulus.

Seasonal differences were observed in the amount of fish caught in each haul by number and weight, in the community of fish caught, and in the populations (length frequency distributions) of the fish caught. Comparisons to determine seasonal differences were made between the hauls conducted with the same window configurations, by the same vessel, in the spring versus the fall. The differences in the amount of fish caught between spring and fall indicate the escape windows may be more or less effective according to season. For instance, differences observed suggest that the square mesh window configuration allows more undersize fish to escape in the fall than in the spring.

The differences in the amount of fish caught and the difference in the escape efficiency of the windows between the seasons may be due to differences in the communities of fish and differences in the populations (length frequency distributions) of the fish. Haddock, pollock, and winter flounder were more abundant in the spring. Monkfish and witch flounder (grey sole) were more abundant in the fall. Seasonal differences were found in the populations, as indicated by length frequency distributions, of dab (American plaice), winter flounder, yellowtail flounder and cod. A larger portion of the populations of dab and cod were small, and under the legal size limits, in the fall. The opposite was found for yellowtail and winter flounder, where a larger portion of their populations were small and under legal size limits in the spring.

Vessel Differences

Complicating evaluating the differences among window configurations is the fact that only two vessels were used to complete the testing. Catch efficiency varies among fishing vessels. Due to this variation in fishing efficiency between vessels, the effectiveness of the window configurations at reducing bycatch and discard of undersize fish was examined separately according to vessels.

The F/V Christopher Andrew completed tows for each escape window in the spring and in the fall. The F/V North Star completed tows for each escape window in the fall only. While the F/V Christopher Andrew is a slightly larger vessel, the net used by the F/V North Star had a much greater fishing circle. In addition to differences in the nets, the vessels sampled different areas in the Gulf of Maine. The F/V Christopher Andrew sampled east of Scituate, MA and the F/V North Star sampled east of Portland, ME.

The vessel appears to have influenced the efficiency of the catch of each window configuration. In a comparison between the hauls conducted by the same window configuration between the vessels (for hauls conducted in the fall only by both vessels), the F/V Christopher Andrew caught and kept significantly more than the F/V North Star, while it discarded significantly less. This indicates that the escape windows were more effective on the F/V Christopher Andrew, at reducing the bycatch and discard of undersize fish.

The vessels caught different populations of fish, based on length frequency distributions. A larger portion of the populations of dab and cod were smaller and under the legal size limits in hauls conducted by the F/V Christopher Andrew. The opposite was found for witch flounder, with a larger portion of their population being small and undersize in hauls conducted by the F/V North Star. In addition, yellowtail were more abundant in hauls conducted by the F/V Christopher Andrew, and virtually absent in the hauls conducted by the F/V North Star.

The difference observed in the haul amounts, in the populations of fish sampled, and in the efficiency of the escape windows could be due to the differences in the vessels including differences in the nets used by each vessel, where the net used by the F/V Christopher Andrew had a smaller fishing circle. The difference could also be due to the F/V Christopher Andrew conducting its hauls earlier in the fall (October) and the F/V North Star conducting its trawls latter in the season (November through December).

Evaluation of Escape Windows

Due to the observed differences between the seasons and vessels it was necessary to evaluate the window configurations separately according to both season and vessel, as both likely influenced the fishing efficiency of the window configurations. Unfortunately, evaluating differences among the window configurations separately according to vessel and season lowered the number of hauls being compared. With a lower N value, differences in the catch efficiency between the windows may have been less obvious with fewer statistically significant differences.

Both the vessel and the season influenced the efficiency of the window configurations. Differences among the window configurations were observed in both the spring and fall, for each vessel, but overall, when all hauls conducted in both seasons, by both vessels, were evaluated together no differences were observed in the catch and discard of nets with the different window configurations.

Neither the square nor the hexagonal mesh appears to consistently and significantly reduce the bycatch and discard of undersize fish. A reduction in bycatch of undersize fish was indicated for some species, but the results were not consistent between the seasons or the vessels. For instance, in the spring the nets with the square mesh allowed more fish, of both legal and sub-legal sizes to escape through the window better than the hexagonal mesh. The square mesh appeared to decrease the bycatch of undersize cod and winter flounder, but it also decreased the catch of the targeted, larger sizes, of each species.

The opposite trend was found in the fall. In general the hexagonal mesh appeared to allow more targeted and non-targeted (bycatch and undersize fish) fish to escape through the window than the square mesh, thereby reducing both the overall kept and discarded catches. This generalization was not consistent for each species or for each vessel.

On the F/V Christopher Andrew, the use of square mesh and the presence of the black tunnel decreased the discard of undersize monkfish. The opposite was found for flatfish. The nets with the hexagonal mesh windows decreased the discard of undersize flatfish, while maintaining the quantity of kept flatfish. When the catches of each flatfish was examined separately the generalization that the hexagonal mesh was better than the square mesh did not hold. The nets with the square mesh windows decreased the catch of both undersize and legal sized winter flounder, while the nets with the hexagonal mesh decreased the catch of both undersize and legal sized witch flounder.

No differences were observed in the overall quantity of fish caught by the nets with the square and hexagonal mesh windows on the F/V North Star. Despite there being no overall differences, the nets with the square mesh windows decreased the bycatch of both skates and invertebrates. The opposite was found for dabs, with the nets with the hexagonal mesh in the escape windows decreased the discard of undersize dabs.

Evaluation of the black tunnel visual stimulus

The purpose of the black tunnel was to visually stimulate the fish to challenge the mesh of the escape windows. As the natural behavior of the fish is to avoid the mesh (Glass et. Al 1995), the presence of the visual stimulus would increase the escapement rate and therefore decrease the bycatch and discard of undersize fish. In this study, the nets with the black tunnel visual stimulus did not have consistently or significantly less bycatch or discard. This is somewhat surprising given the nature of responses seen in other published studies. However, water clarity was poor, both in terms of clarity and ambient light intensity at fishing depth as determined by inability of the underwater camera to form images throughout most of this study. The camera ceases to form functional images at approximately 10^{-3} lux, a light intensity only slightly higher than light intensity required for fish to form visual images (Glass et al. 2002). Reaction to the presence of the visual stimulus requires that the visual system be capable of forming visual images. Furthermore it requires that the visual stimulus be a sharply contrasting stimulus. As light intensity decreases, so does contrast, thereby rendering the visual stimulus less effective. The results of this study appear to suggest that fishing operations may have been conducted at light intensities near, at, or below the absolute visual threshold of fish hence the lack of obvious difference between catches with or without the visual stimulus. In general, ambient light intensity at fishing depth is a recurrent issue in conducting studies such as this in the Gulf of Maine on commercial fishing grounds. Further studies aimed at a better understanding of the nature of the underwater light field on commercial fishing grounds would determine the degree to which fish reactions are visually mediated. This in turn would help determine the potential effectiveness of approaches such as those reported here.

Conclusion

Overall, it appears that neither the use of square or hexagonal mesh consistently or significantly decreased the bycatch of undersize fish or non-targeted species. Further, the presence of the black tunnel visual stimulus did not appear to decrease the discard of undersize fish through increasing their escape through the windows. In addition the results suggest the escape windows may be more or less effective, depending on season, area, and vessel.

FINDINGS

Actual accomplishments and findings

This study investigated the effectiveness of two escape window configurations, one with 7" hexagonal mesh the other with 7" square mesh at reducing the bycatch and discard of undersize fish in the Gulf of Maine Groundfish fishery. Both escape windows were tested with and without the addition of a visual stimulus, in the form of a black tunnel. As the natural behavior of fish is to avoid the meshes of netting around them, the purpose of the black tunnels was to visually stimulate the fish to challenge the mesh netting and therefore increase their escapement rate.

As previous studies identified seasonal variation in the selective efficiency of codends in the Gulf of Maine (Glass et al. 2002), the four window configurations were tested in both the spring and the fall. Three vessels were used to complete the hauls. The F/V Christopher Andrew completed hauls in both the spring and the fall and the F/V North Star completed hauls in the fall. A third vessel had been scheduled to complete hauls in the spring, but unfortunately due to the required use of a DAS, the vessel was unable to participate.

Overall, the bycatch and discard of undersize fish was not constantly or significantly affected by either the escape window configuration (mesh type) or the presence/absence of the additional black tunnel visual stimulus. Unfortunately, in this study, no hauls with the standard (control) net configurations were completed due to time and vessel constraints. Therefore, it was not possible to evaluate the escape windows effectiveness at reducing bycatch in comparison to the standard gear. It is possible, and highly likely that the use of the nets with the escape windows, both with 7" hexagonal and 7" square mesh, reduced overall discard of undersize fish by allowing their escape through the window mesh.

The results of the comparative analysis between the four window configurations indicated the season influenced the fishing efficiency of the window configurations. Seasonal differences were observed in the amount of fish caught in each haul (both by number of individuals and weight), in the community of fish caught, and in the populations of fish caught (length frequency distributions). The differences observed between the populations of fish caught in the spring and fall suggests that the square mesh window configuration allows more undersize fish to escape in the fall than in the spring. Differences in the amount of fish caught and in the escape efficiency of the windows between seasons may be attributed to differences in the communities and populations (length frequency distributions) of fish between the seasons.

In addition, the results indicate that the fishing efficiency of the window configurations was affected by the vessel. The comparison of hauls conducted by the vessels conducted in the fall indicates the escape windows were more effective at reducing the bycatch and discard of undersize fish on the F/V Christopher Andrew. The F/V Christopher Andrew caught and kept significantly more than the F/V North Star, while it discarded significantly less.

The overall comparative analysis of fishing efficiency among the window configurations (hexagonal and square mesh) with and without the black tunnel visual stimulus was evaluated separately according to both season and vessel, due to the differences observed between the seasons and vessels (as described above). Neither the square nor the hexagonal mesh consistently and significantly reduced the bycatch and discard of undersize fish. A reduction in bycatch of undersize fish was indicated for some species, but the results were not consistent between the seasons and the vessels. In addition, the presence of the black tunnel visual stimulus did not appear to increase the escapement rate of the fish, as no significant decrease was observed in the amount of bycatch and discard of undersize fish for either the hexagonal or square mesh window configurations.

Significant problems and description of additional work

The original proposal called for covered codends to be used in this study in order for selectivity parameters to be estimated. However, it was determined through discussions with the fishermen involved that covered codends were not feasible. This was due to the fact two covered would have been necessary, one to cover the codend and the other to cover the escape window. As the escape window spans the circumference of the net, the cover would have had to encircle the net. Further, one of the codend covers would have had to be within the other. Due to these technical difficulties, fishing with two covers was not considered to be particle for us in commercial fishing conditions, despite the participants willingness to attempt to do so during preliminary stages of the proposal. Therefore, the selectivity parameters could not be calculated as originally planned. A solution to the problem was to fish with a small mesh (4" diamond) codend, which would retain all fish not escaping through the windows.

Despite this enforced change in the experimental protocol, data analysis has failed to identify significant differences in length frequencies for fish retained by the experimental nets for either vessel or in either season. Therefore a selectivity analysis would have yielded little or no additional information to this project.

A second challenge encountered in this project was the last minute cancellation of one of the participating vessels. Only two vessels were used to test the four escape window configurations, one in the spring and two in the fall. This project was originally split into two separate experimental portions. Experimental fishing permits were initially issued for the first set of experimental sea trials (spring trials) and PI's were required to submit requests for EFP's for the second set of sea trials (conducted in the fall). During the first stage vessels were permitted exemption from the DAS regulation. However, prior to the start of the second set of trials, a change in the DAS requirements occurred. No DAS exemption was permitted for the sea trials conducted in the fall. This change in policy led to the last minute cancellation of the third participating vessel.

Another consequence of the imposition of the use of a DAS was that the cost for each sea day increased. Therefore fewer sea days were affordable and the experimental protocol had to be adjusted accordingly. To compensate for less time conducting the sea trials, hauls of the standard nets used in the Gulf of Maine groundfish fishery could not be completed. This limited the evaluation of the fishing efficiency of the four experimental escape window configurations. Only a comparative analysis among the escape window configurations could be completed. It is possible, and highly likely, that the use of nets with escape windows reduces the overall discard of undersize fish through allowing their escape through the window mesh, in comparison to standard nets, but unfortunately this could not be evaluated in this study.

Escape windows and visual stimuli have been successfully employed by other countries as a management measure to reduce the bycatch and discard of undersize fish. Additional study on the use of escape windows and visual stimuli would be necessary to find the technique that would be successful in the Gulf of Maine groundfish fishery. Further, as the results from this study indicated that both the vessel and season affects the fishing efficiency of the escape windows, additional study would be needed to determine what window configuration would maximize the escape of fish for different vessels in both the spring and the fall.

EVALUATION

A few, unavoidable changes were made from the original proposal; therefore, not all project objectives could be met. Although changes were made, overall we consider this project to be successful and to have provided valuable information on the performance of the experimental net configurations. It was completed with the active participation of fishermen and the fishing industry and produced valuable scientific information on two escape window configurations and the addition of the black tunnel visual stimulus. The project successfully tested and compared the fishing efficiency of the escape windows on multiple vessels during two seasons.

The results from the experimental sea trials in the Gulf of Maine indicate that neither the use of square or hexagonal mesh consistently or significantly decreased the bycatch of undersize fish or non-target species. Further, the presence of the black tunnel visual stimulus does not appear to decrease the discard of undersize fish through increasing their escape through the windows. Although we speculate the findings are due to the low light levels in the Gulf of Maine (see discussion above) future study would be required to understand the actual reasons the escape windows and additional visual stimuli failed to increase the escape of undersize fish. The use of escape windows and visual stimuli has been successfully employed by other countries as a management measure to reduce the bycatch and discard of undersize fish. Additional study on the use of escape windows and visual stimuli would be necessary to find the technique that would be successful in the Gulf of Maine groundfish fishery.

The results of this study can be presented to appropriate staff members of the New England Fisheries Management Council and all other interested groups upon request. It is the intent of the principal investigators to prepare the results as a short communication for peer reviewed scientific publication. The final report will be posted as a PDF file on the World Wide Web sites of the NOAA Fisheries Cooperative Research Partners Program and Manomet Center for Conservation Sciences. All participants in the program of research will obtain a hard copy of the final report and hard copies will be made available to all interested parties who do not have access to the World Wide Web.

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Table 2. The number of hauls completed for each window configuration by the F/V Christopher Andrew east of Scituate, MA and by the F/V North Star east of Portland, ME according to season (spring or fall).

*Note that in the fall 1 of the 7 hauls conducted by the Christopher Andrew for the 7" sq window with the tunnel off was not valid, as it lasted only 4 minutes, therefore a total of only 33 valid hauls were conducted for the 7" sq window with the tunnel off.

		Spring			Fall			Pooled Seasons	
Mesh	Tunnel	Christopher Andrew East of Scituate	North Star East of Portland	Total	Christopher Andrew East of Scituate	North Star East of Portland	Total	Christopher Andrew	Total
7 Hex	Off	10	0	10	6	15	21	16	31
7 Hex	On	10	0	10	6	15	21	16	31
7 Sq	Off	11	0	11	7*	16	23*	18*	34*
7 Sq	On	10	0	10	6	15	21	16	31

Table 7. The mean catch in terms of CPUE by disposition (total, kept, discard, and discard of undersize fish) for each category of fish for the four window configurations according to vessel and season for a)weight (pounds/hour) and b)number of individuals (#/hour). The categories are as follows: flatfish (Dabs, Witch Floudner, Winter Floundar, Yellowtail Flounder and Halibut), roundfish (Cod, Haddock, White Hake, and Pollock), monkfish, spiny dogfish, skates, invertebrates, and other. The 'other' category contains species that composed approximately 1% or less of the total catch. Note that the total discard includes the discard of undersize fish, while the discard of undersize fish refers only to commercially important fishes discarded for being below the minimum legal size.

Table 7a) Mean weights (CPUE)

Total

Season	Spring Hauls				Fall Hauls												Both seasons							
Vessel	Christopher Andrew				Christopher Andrew				North Star				Both Vessels				Christopher Andrew				Both Vessels			
Mesh	7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq	
Tunnel	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON
Roundfish	400	563	346	182	83	123	144	261	46	30	48	47	56	56	74	108	281	398	275	211	167	220	165	132
Flatfish	702	562	412	319	388	399	379	458	73	70	77	74	163	184	159	183	584	501	400	371	337	293	243	227
Spiny Dogfish	148	154	34	177	751	945	1366	1096	225	197	746	343	375	411	915	558	373	451	504	522	301	328	621	435
Monkfish	8	4	18	8	113	74	518	667	242	188	232	233	205	156	310	357	47	30	193	255	141	107	212	245
Skates	240	292	187	220	59	103	96	100	62	75	30	33	61	83	48	52	172	221	155	175	119	150	94	107
Invertebrates	9	5	2	5	0	4	0	2	39	40	20	14	28	30	14	10	6	4	1	4	22	22	10	9
Other	269	182	304	291	142	120	165	228	33	6	29	11	64	38	66	73	222	159	255	267	130	85	145	143

Kept

Season	Spring Hauls				Fall Hauls												Both seasons							
Vessel	Christopher Andrew				Christopher Andrew				North Star				Both Vessels				Christopher Andrew				Both Vessels			
Mesh	7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq	
Tunnel	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON
Roundfish	292	474	264	134	29	60	58	143	26	23	40	38	27	33	45	68	193	318	191	138	112	175	118	89
Flatfish	431	368	282	205	296	328	253	349	31	26	31	22	107	112	92	116	358	353	272	259	200	195	155	145
Spiny Dogfish	0	0	0	0	0	0	0	0	0	0	0	0	0			0								
Monkfish	7	4	15	8	106	67	508	660	195	153	192	198	170	129	278	330	44	28	189	253	117	88	190	226
Skates	0	0	0	0	0		0		0	0	0	0	0											
Invertebrates	1	1	2	1	0			0	0	0	0	0	0	0	0	0	1	1	1	0	0	1	1	0
Other	13	21	38	13	0	0	16	0	26	3	1	0	21	2	5	0	12	13	30	8	19	8	16	4

Discard

Season	Spring Hauls				Fall Hauls												Both seasons							
Vessel	Christopher Andrew				Christopher Andrew				North Star				Both Vessels				Christopher Andrew				Both Vessels			
Mesh	7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq	
Tunnel	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON
Roundfish	108	89	82	47	54	64	87	118	20	7	8	9	29	23	29	40	88	80	84	74	55	45	47	42
Flatfish	396	194	130	114	92	71	126	109	42	44	46	51	56	52	66	68	226	148	128	112	137	98	88	82
Spiny Dogfish	146	154	34	177	751	945	1366	1096	225	197	746	343	375	411	915	558	373	451	504	522	301	328	621	435
Monkfish	1	0	1	0	7	7	10	7	47	35	40	36	38	27	32	27	3	3	4	3	24	18	21	19
Skates	240	292	187	220	59	103	96	100	62	75	30	33	61	83	48	52	172	221	155	175	119	150	94	107
Invertebrates	8	4	0	4	9	3	0	2	39	40	20	14	28	29	14	10	5	3	0	3	22	21	10	8
Other	241	190	255	309	99	102	218	179	4	6	16	8	32	33	71	57	188	157	242	260	99	84	132	138

Discard of undersize fish

Season	Spring Hauls				Fall Hauls												Both seasons							
Vessel	Christopher Andrew				Christopher Andrew				North Star				Both Vessels				Christopher Andrew				Both Vessels			
Mesh	7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq	
Tunnel	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON
Roundfish	108	89	82	47	54	64	80	118	5	1	3	5	19	19	24	37	88	80	81	74	48	42	43	40
Flatfish	306	194	130	114	92	67	126	105	41	44	46	49	56	51	67	65	226	147	128	111	137	97	88	81
Spiny Dogfish	0	0		0																				
Monkfish	1	0	1	0	7	7	10	7	47	35	40	33	38	27	32	25	3	3	4	3	24	18	21	17
Skates	0	0		0	0																			
Invertebrates	0	1	0	0	0	1		0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0

Table 7b). Mean numbers (CPUE)

Total

Season	Spring Hauls				Fall Hauls												Both seasons							
Vessel	Christopher Andrew				Christopher Andrew				North Star				Both Vessels				Christopher Andrew				Both Vessels			
Mesh	7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq	
Tunnel	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON
Roundfish	126	142	109	55	43	49	84	105	5	3	7	7	16	16	28	35	95	107	100	74	51	57	55	42
Flatfish	969	710	483	401	428	418	525	572	152	140	143	150	230	219	247	271	786	601	497	465	469	378	326	313
Monkfish	2	1	2	1	18	13	68	98	80	70	76	76	63	53	74	82	8	5	25	38	43	37	50	56
Other				0							0				0					0			0	0

Kept

Season	Spring Hauls				Fall Hauls												Both seasons							
Vessel	Christopher Andrew				Christopher Andrew				North Star				Both Vessels				Christopher Andrew				Both Vessels			
Mesh	7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq	
Tunnel	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON
Roundfish	73	93	67	31	5	6	10	24	3	2	5	5	3	3	6	11	47	60	46	28	26	32	26	17
Flatfish	248	257	225	156	240	258	204	267	44	35	40	32	100	98	84	99	245	257	218	198	147	150	131	118
Monkfish	1	1	2	1	13	11	56	92	38	34	38	41	31	28	43	56	6	4	21	35	21	19	29	38
Other											0				0					0			0	0

Discard

Season	Spring Hauls				Fall Hauls												Both seasons							
Vessel	Christopher Andrew				Christopher Andrew				North Star				Both Vessels				Christopher Andrew				Both Vessels			
Mesh	7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq	
Tunnel	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON
Roundfish	53	49	43	24	39	43	75	81	2	1	1	2	12	13	21	24	48	47	54	46	26	25	28	24
Flatfish	721	453	257	245	188	160	321	305	108	105	103	118	131	121	163	171	521	343	280	268	321	228	194	195
Monkfish	1	0	1	0	5	3	12	6	43	35	38	35	32	26	31	26	2	1	5	2	22	18	21	18
Other				0							0				0								0	0

Discard of undersize fish

Season	Spring Hauls				Fall Hauls												Both seasons							
Vessel	Christopher Andrew				Christopher Andrew				North Star				Both Vessels				Christopher Andrew				Both Vessels			
Mesh	7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq	
Tunnel	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON
Roundfish	53	49	43	24	39	43	75	81	2	1	1	2	12	13	21	24	48	47	54	46	26	25	28	24
Flatfish	594	370	221	222	188	160	321	305	108	105	103	118	131	121	163	171	442	291	256	253	280	201	182	188
Monkfish	1	0	1	0	5	3	12	6	43	35	38	35	32	26	31	26	2	1	5	2	22	18	21	18
Other											0				0								0	0

Table 8. The mean catch in terms of CPUE by disposition (total, kept, discard and discard of undersize fish) for the commercially important roundfish and flatfish by a) weight (pounds/hour) and b) number of individuals (number/hour) for hauls conducted in the spring, in the fall by the Christopher Andrew, in the fall by the North Star, in the fall for hauls conducted by each vessel pooled together, and for all hauls conducted (pooled seasons and veseels). Note that the total discard includes the discard of undersize fish, while the discard of undersize fish refers only to commercially important fishes discarded for being below the minimum legal size

Table 8a) Weight (CPUE)

Total

Season	Spring				Fall												Pooled Seasons							
Vessel	Christopher Andrew				Christopher Andrew				North Star				Both				Christopher Andrew				Both			
Mesh	7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq	
Tunnel	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On
Cod	205	247	119	93	76	121	129	216	30	21	37	40	43	49	62	91	157	200	122	139	95	95	81	91
Dab (American Plaice)	94	25	6	65	62	31	117	85	16	16	12	15	29	20	40	35	82	27	45	73	50	50	29	45
Haddock	181	216	227	89	6	3	15	44	0	0	1	0	2	1	5	13	116	136	152	72	60	60	79	37
Hake	0	0	0	0	0	0	0	0	14	9	10	6	10	6	7	5	0	0	0	0	7	7	5	3
Halibut	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pollock	13	100	0	0	0	0	0	0	2	0	0	0	1	0	0	0	8		0	0	5	5	0	0
Winter Flounder	312	291	214	152	183	228	2	4	2	1	1	1	54	66	1	2	283	268	139	96	137	137	72	50
Witch Flounder (grey sole)	1	1	1	3	75	54	173	322	54	52	64	58	60	53	94	133	28	21	62	122	41	41	63	91
Yellowtail Flounder	296	244	191	100	69	86	86	46	1	1	1	0	21	25	24	13	211	184	154	79	109	109	80	41

Kept

Season	Spring				Fall												Pooled Seasons							
Vessel	Christopher Andrew				Christopher Andrew				North Star				Both				Christopher Andrew				Both			
Mesh	7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq	
Tunnel	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On
Cod	115	167	52	53	24	58	42	99	25	20	34	36	25	31	37	54	81	126	48	70	54	75	42	54
Dab (American Plaice)	33	14	4	16	9	5	14	10	3	1	2	1	4	2	5	4	24	11	7	14	14	6	5	8
Haddock	164	206	212	81	4	2	15	44	0	0	1	0	1	0	4	13	104	129	142	67	54	67	74	35
Hake	0	0	0	0	0	0	0	0	0	3	5	2	0	2	4	1	0	0	0	0	0	1	3	1
Halibut	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pollock	13	100	0	0	0	0	0	0	2	0	0	0	1	0	0	0	8		0	0	5	32	0	0
Winter Flounder	207	218		121	172	216	2	4	2	1	1	1	51	63	1	2	194	217	104	77	101	113	54	40
Witch Flounder (grey sole)	1	1	1	2	72	53	160	293	26	23	29	20	39	32	64	98	27	20	57	111	26	22	43	67
Yellowtail Flounder	155	135	117	67	43	54	77	42	1	0	0	0	13	16	21	12	113	104	103	57	59	54	53	30

Discard

Season	Spring				Fall												Pooled Seasons							
Vessel	Christopher Andrew				Christopher Andrew				North Star				Both				Christopher Andrew				Both			
Mesh	7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq	
Tunnel	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On
Cod	90	79	67	39	52	63	87	118	5	1	3	4	19	19	26	37	76	73	74	69	42	38	39	38
Dab (American Plaice)	61	11	2	50	53	26	103	75	13	15	10	14	24	18	35	31	58	17	38	59	36	16	24	37
Haddock	18	10	15	8	2	1	0	0	0	0	0	0	1	0	0	0	12	7	10	5	6	3	5	3
Hake	0	0	0	0	0	0	0	0	14	6	5	4	10	4	3	3	0	0	0	0	7	3	2	2
Halibut	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Pollock	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	63	0	0	0	0	0	0
Winter Flounder	104	73		31	11	12	0	0	0	0	0	0	3	4	0	0	69	50	35	19	36	26	18	10
Witch Flounder (grey sole)	0	0	0	1	3	1	13	29	28	28	35	37	21	21	29	35	1	1	5	11	14	14	19	24
Yellowtail Flounder	141	109	74	33	26	32	9	4	0	1	1	0	7	9	3	1	98	80	51	22	51	42	27	11

Discard of undersize fish

Season	Spring				Fall												Pooled Seasons							
Vessel	Christopher Andrew				Christopher Andrew				North Star				Both				Christopher Andrew				Both			
Mesh	7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq	
Tunnel	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On
Cod	90	79	67	39	52	63	80	118	5	1	3	4	19	19	24	37	76	73	72	69	42	38	38	38
Dab (American Plaice)	61	11	2	50	53	26	103	75	13	15	10	14	24	18	35	31	58	17	38	59	36	16	24	37
Haddock	18	10	15	8	2	1	0	0	0	0	0	0	1	0	0	0	12	7	10	5	6	3	5	3
Hake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Halibut	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Pollock	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0
Winter Flounder	104	73		31	11	8	0	0	0	0	0	0	3	3	0	0	89	49	35	19	36	25	18	10
Witch Flounder (grey sole)	0	0	0	1	3	1	13	26	28	28	35	35	21	21	29	32	1	1	5	10	14	14	19	22
Yellowtail Flounder	141	109	74	33	26	32	9	4	0	1	1	0	7	9	3	1	98	80	51	22	51	42	27	11

Table 8b) Number of individual (CPUE)

Total

Season	Spring				Fall																Pooled Seasons							
Vessel	Christopher Andrew				Christopher Andrew				North Star				Both				Christopher Andrew				Both			
Mesh	7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq	
Tunnel	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On
Cod	65	64	43	29	37	46	80	94	5	3	6	7	14	15	26	32	54	57	56	53	30	31	32	31
Dab (American Plaice)	155	36	5	124	125	79	301	259	42	40	31	41	65	51	104	103	144	52	110	174	94	46	71	110
Haddock	60	66	66	26	6	4	4	11	0	0	1	0	2	1	1	3	40	43	44	21	20	22	23	11
Hake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Halibut	2	1	2	1	18	13	68	98	80	70	76	76	63	53	74	82	8	5	25	38	43	36	50	56
Pollock	2	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	7	0	0	1	4	0	0
Winter Flounder	349	312	223	146	143	165	1	2	1	1	1	1	42	48	1	1	272	257	145	92	141	133	75	48
Witch Flounder (grey sole)	0	1	1	3	58	41	134	258	107	97	111	106	93	81	118	151	22	16	48	98	63	55	79	103
Yellowtail Flounder	465	361	254	129	102	132	88	53	2	1	1	1	30	39	24	16	328	275	195	101	170	143	101	52

Kept

Season	Spring				Fall												Pooled Seasons							
Vessel	Christopher Andrew				Christopher Andrew				North Star				Both				Christopher Andrew				Both			
Mesh	7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq	
Tunnel	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On
Cod	20	20	8	8	3	6	8	13	3	2	5	5	3	3	6	7	14	15	8	10	9	9	6	8
Dab (American Plaice)	33	12	2	14	8	6	14	9	4	2	2	1	5	3	5	3	24	10	6	12	14	6	4	7
Haddock	51	61	59	23	1	1	2	11	0	0	0	0	0	0	1	3	32	39	39	19	17	20	20	10
Hake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Halibut	1	1	2	1	13	11	56	92	38	34	38	41	31	28	43	56	6	4	21	35	21	19	29	38
Pollock	2	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	7	0	0	1	4	0	0
Winter Flounder	159	180	135	98	124	146	1	2	1	1	0	1	36	42	1	1	146	167	88	62	76	86	46	32
Witch Flounder (grey sole)	0	0	1	2	53	39	117	211	37	32	38	30	41	34	59	82	20	15	41	80	28	23	40	56
Yellowtail Flounder	56	64	87	43	54	67	72	46	2	1	0	0	17	20	20	13	55	66	82	44	29	34	42	23

Discard

Season	Spring				Fall												Pooled Seasons							
Vessel	Christopher Andrew				Christopher Andrew				North Star				Both				Christopher Andrew				Both			
Mesh	7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq	
Tunnel	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On
Cod	44	44	36	21	34	40	73	81	2	1	1	2	11	12	21	24	40	43	49	44	22	22	26	23
Dab (American Plaice)	122	23	3	110	117	73	287	251	38	39	29	40	60	49	99	100	120	42	103	163	80	41	67	103
Haddock	9	5	7	3	4	3	2	0	0	0	0	0	1	1	1	0	7	4	5	2	4	2	3	1
Hake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Halibut	1	0	1	0	5	3	12	6	43	35	38	35	32	26	31	26	2	1	5	2	22	18	21	18
Pollock	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Winter Flounder	190	132	88	48	18	20	0	0	0	1	0	0	5	6	0	0	126	90	57	30	65	47	29	16
Witch Flounder (grey sole)	0	1	0	1	4	3	18	47	70	65	74	77	51	47	58	69	2	1	6	18	35	32	39	47
Yellowtail Flounder	409	297	167	86	47	64	16	8	0	1	1	0	14	19	5	2	273	210	114	57	141	109	59	30

Discard of undersize fish

Season	Spring				Fall												Pooled Seasons							
Vessel	Christopher Andrew				Christopher Andrew				North Star				Both				Christopher Andrew				Both			
Mesh	7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq		7 Hex		7 Sq	
Tunnel	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On
Cod	44	44	36	21	34	40	73	81	2	1	1	2	11	12	21	24	40	43	49	44	22	22	26	23
Dab (American Plaice)	122	23	3	110	117	73	287	251	38	39	29	40	60	49	99	100	120	42	103	163	80	41	67	103
Haddock	9	5	7	3	4	3	2	0	0	0	0	0	1	1	1	0	7	4	5	2	4	2	3	1
Hake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Halibut	1	0	1	0	5	3	12	6	43	35	38	35	32	26	31	26	2	1	5	2	22	16	21	18
Pollock	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Winter Flounder	190	132	88	48	18	20	0	0	0	1	0	0	5	6	0	0	126	90	57	30	65	47	29	16
Witch Flounder (grey sole)	0	1	0	1	4	3	18	47	70	65	74	77	51	47	58	69	2	1	6	18	35	32	39	47
Yellowtail Flounder	282	214	130	64	47	64	16	8	0	1	1	0	14	19	5	2	194	158	90	43	100	82	47	22

Table 10. Results of the Kruskal-Wallis analysis of variance indicating differences in a) weight (CPUE) and b)number (CPUE) for each category of fish caught (roundfish, flatfish, monkfish, spiny dogfish, invertebrates, skates and other) among the four window configurations tested. A p value of <0.05 indicates significant differences.

Table 10a) Kruskal-Wallis results for differences in weight (CPUE)

		Spring	Fall			pooled seasons	
		Christopher Andrew	Christopher Andrew	North Star	both	Christopher Andrew	both
Roundfish	Total Discard	0.1	0.318	0.045	0.269	0.973	0.626
	Dicarded - undersize fish	0.1	0.318	0.236	0.201	0.977	0.768
	Total Kept	0.429	0.478	0.806	0.585	0.848	0.925
	Total Catch	0.133	0.271	0.477	0.498	0.858	0.979
Flatfish	Total Discard	0.727	0.196	0.974	0.805	0.747	0.896
	Dicarded - unersize fish	0.727	0.182	0.976	0.808	0.681	0.873
	Total Kept	0.061	0.577	0.835	0.988	0.658	0.913
	Total Catch	0.101	0.682	0.997	0.982	0.699	0.968
Spiny Dogfish	Total Discard	0.319	0.396	0.505	0.203	0.685	0.569
	Total Catch	0.319	0.396	0.505	0.203	0.685	0.569
Monkfish	Total Discard	0.523	0.301	0.398	0.709	0.606	0.936
	Dicarded - undersize fish	0.523	0.301	0.3	0.625	0.606	0.899
	Total Kept	0.406	0.007	0.682	0.011	0.296	0.236
	Total Catch	0.537	0.008	0.716	0.019	0.432	0.334

		Spring	Fall			pooled seasons	
		Christopher Andrew	Christopher Andrew	North Star	both	Christopher Andrew	both
Invertebrates	Total Discard	0.089	0.287	0.011	0.077	0.075	0.027
	Dicarded - undersize fish	0.509	0.1	1	0.099	0.552	0.084
	Total Kept	0.551	0.392	1	0.377	0.618	0.605
	Total Catch	0.583	0.287	0.011	0.067	0.092	0.045
Skates	Total Discard	0.669	0.476	0.021	0.093	0.661	0.297
	Total Catch	0.669	0.476	0.021	0.093	0.661	0.297
Other	Total Discard	0.142	0.076	0.157	0.219	0.092	0.411
	Dicarded - undersize fish	1	1	0.551	0.548	1	0.549
	Total Kept	0.625	0.106	0.543	0.085	0.545	0.507
	Total Catch	0.188	0.23	0.134	0.279	0.142	0.372

Table 10b) Kruskal-Wallis results for differences in number (CPUE)

		Spring	Fall			pooled seasons	
		Christopher Andrew	Christopher Andrew	North Star	both	Christopher Andrew	both
Roundfish	Total Discard	0.085	0.198	0.515	0.32	0.997	0.825
	Dicarded - undersize fish	0.085	0.198	0.515	0.32	0.997	0.825
	Total Kept	0.388	0.4	0.591	0.259	0.976	0.987
	Total Catch	0.177	0.214	0.297	0.251	0.978	0.804
Flatfish	Total Discard	0.648	0.024	0.995	0.673	0.861	0.924
	Dicarded - undersize fish	0.727	0.024	0.995	0.673	0.847	0.909
	Total Kept	0.219	0.692	0.84	0.942	0.666	0.829
	Total Catch	0.334	0.466	0.996	0.924	0.95	0.963
Monkfish	Total Discard	0.334	0.039	0.805	0.881	0.284	0.913
	Dicarded - undersize fish	0.334	0.039	0.805	0.881	0.284	0.913
	Total Kept	0.566	0.002	0.98	0.02	0.296	0.768
	Total Catch	0.319	0.002	0.918	0.21	0.36	0.542
Other	Total Discard	0.376	1	0.421	0.434	0.382	0.586
	Total Catch	0.376	1	0.421	0.434	0.382	0.586

Table 11. Results of the Kruskal-Wallis analysis of variance indicating differences in a) weight (CPUE) and b)number (CPUE) for the commercially important fish caught among the four window configurations tested. A p value of <0.05 indicates significant differences.

Table 11 a) Kruskal-Wallis results for differences in weights

		p-value					
		spring	fall			both	
Species	Disposition	Christopher Andrew	Christopher Andrew	North Star	both	Christopher Andrew	both
Cod	Total Discard	0.079	0.318	0.239	0.281	0.99	0.657
	Dicarded - too small	0.079	0.318	0.239	0.281	0.99	0.857
	Total Kept	0.029	0.452	0.886	0.68	0.238	0.923
	Total Catch	0.007	0.17	0.698	0.501	0.466	0.999
HADDOCK	Total Discard	0.752	0.287	0.577	0.882	0.718	0.907
	Dicarded - too small	0.752	0.287	0.577	0.882	0.718	0.907
	Total Kept	0.742	0.442	0.421	0.553	0.294	0.244
	Total Catch	0.741	0.7	0.314	0.544	0.356	0.209
HAKE	Total Discard	1	1	0.046	0.111	1	0.205
	Dicarded - too small	1	1	1	1	1	1
	Total Kept	1	1	0.355	0.374	1	0.364
	Total Catch	1	1	0.345	0.499	1	0.609
POLLOCK	Total Discard	0.376	1	1	1	0.362	0.382
	Dicarded - too small	0.376	1	1	1	0.382	0.362
	Total Kept	0.243	1	0.381	0.377	0.264	0.238
	Total Catch	0.243	1	0.381	0.377	0.264	0.236

		p-value					
		spring	fall			both	
Species	Disposition	Christopher Andrew	Christopher Andrew	North Star	both	Christopher Andrew	both
DAB	Total Discard	0.257	0.018	0.13	0.545	0.284	0.407
	Dicarded - too small	0.257	0.018	0.131	0.537	0.284	0.411
	Total Kept	0.133	0.316	0.997	0.896	0.572	0.833
	Total Catch	0.156	0.024	0.239	0.666	0.37	0.549
WINTER	Total Discard	0.077	0.025	0.232	0.019	0.2	0.454
	Dicarded - too small	0.077	0.058	0.232	0.057	0.208	0.533
	Total Kept	0.369	0.048	0.366	0.139	0.063	0.326
	Total Catch	0.087	0.049	0.518	0.129	0.034	0.26
WITCH	Total Discard	0.541	0.005	0.981	0.459	0.244	0.78
	Dicarded - too small	0.541	0.044	0.983	0.637	0.458	0.885
	Total Kept	0.577	0.005	0.896	0.606	0.345	0.727
	Total Catch	0.605	0.005	0.949	0.288	0.366	0.605
YELLOWTAIL	Total Discard	0.421	0.16	0.245	0.392	0.188	0.627
	Dicarded - too small	0.421	0.16	0.16	0.392	0.188	0.627
	Total Kept	0.254	0.751	0.751	0.221	0.431	0.511
	Total Catch	0.287	0.659	0.281	0.54	0.334	0.602
HALIBUT	Total Discard	0.376	1	1	1	0.382	0.382
	Dicarded - too small	0.376	1	1	1	0.382	0.382
	Total Kept	1	1	1	1	1	1
	Total Catch	0.376	1	1	1	0.382	0.382

Table 11 b) K-W test results for species by number of individuals

Species	Disposition	p-value: spring Christopher Andrew	fall Christopher Andrew	fall North Star	fall both	both Christopher Andrew	both both
Cod	Total Discard	0.06	0.197	0.364	0.543	0.987	0.922
	Dicarded - too small	0.06	0.197	0.364	0.543	0.987	0.922
	Total Kept	0.002	0.477	0.619	0.418	0.194	0.992
	Total Catch	0.017	0.163	0.364	0.473	0.968	0.955
HADDOCK	Total Discard	0.813	0.549	0.574	0.901	0.63	0.909
	Dicarded - too small	0.813	0.549	0.574	0.901	0.63	0.909
	Total Kept	0.906	0.569	0.46	0.697	0.59	0.463
	Total Catch	0.902	0.912	0.337	0.59	0.743	0.406
POLLOCK	Total Discard	0.376	1	1	1	0.382	0.382
	Dicarded - too small	0.376	1	1	1	0.382	0.382
	Total Kept	0.243	1	0.381	0.384	0.264	0.238
	Total Catch	0.258	1	0.381	0.384	0.274	0.238

Species	Disposition	p-value: spring Christopher Andrew	fall Christopher Andrew	fall North Star	fall both	both Christopher Andrew	both both
DAB	Total Discard	0.268	0.003	0.176	0.28	0.303	0.302
	Dicarded - too small	0.142	0.003	0.176	0.28	0.303	0.302
	Total Kept	0.182	0.329	0.837	0.89	0.605	0.587
	Total Catch	0.148	0.005	0.236	0.316	0.355	0.337
WINTER	Total Discard	0.148	0.023	0.278	0.026	0.206	0.472
	Dicarded - too small	0.148	0.023	0.278	0.026	0.206	0.472
	Total Kept	0.301	0.135	0.346	0.174	0.075	0.391
	Total Catch	0.111	0.135	0.559	0.2	0.058	0.335
WITCH	Total Discard	0.541	0.001	0.955	0.447	0.216	0.816
	Dicarded - too small	0.541	0.001	0.955	0.447	0.216	0.816
	Total Kept	0.532	0.004	0.991	0.355	0.329	0.603
	Total Catch	0.56	0.002	0.993	0.145	0.319	0.586
YELLOWTAIL	Total Discard	0.301	0.124	0.132	0.556	0.166	0.706
	Dicarded - too small	0.422	0.124	0.132	0.556	0.206	0.74
	Total Kept	0.606	0.567	0.128	0.275	0.655	0.893
	Total Catch	0.416	0.396	0.12	0.544	0.391	0.645
HALIBUT	Total Discard	0.376	1	1	1	0.382	0.382
	Dicarded - too small	0.376	1	1	1	0.382	0.382
	Total Kept	1	1	1	1	1	1
	Total Catch	0.378	1	1	1	0.382	0.382

Figure 1. Diagrammatic representation of the escape windows

Figure 1a. Diagrammatic representation of a 7" square mesh escape window and its position in relation to the small-mesh (4") diamond codend. Figure 1b shows the 2m long black panel inserted at the aft end of the escape window.

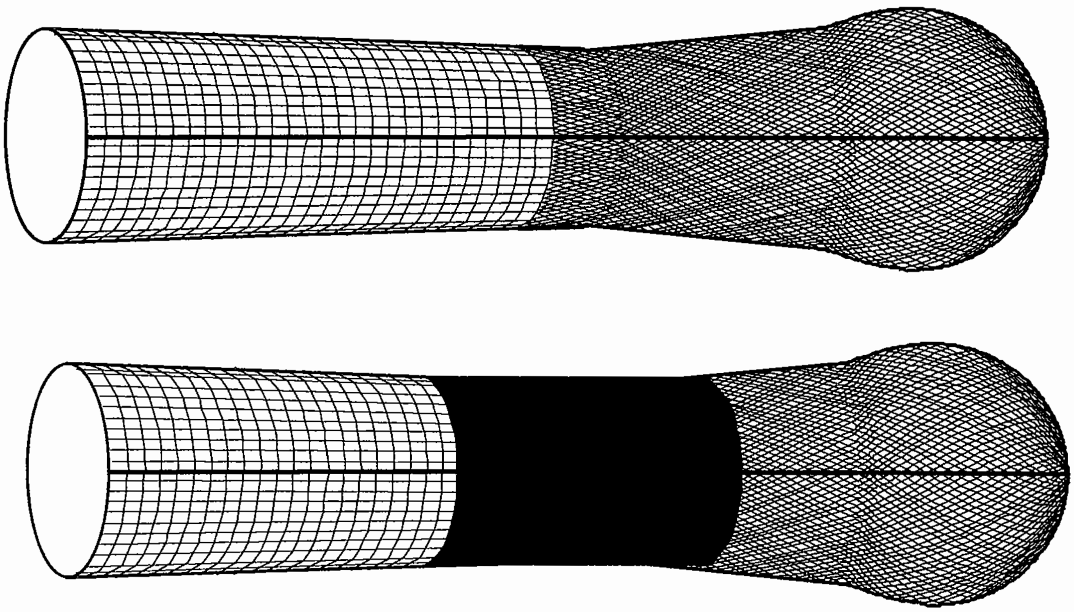


Figure 1b. Illustration of a hexagonal-mesh escape window with and without the black panel visual-stimulus in place. The hexagonal-mesh window will be identical in size and rigged in precisely the same location in the net. The small mesh codend is omitted from this figure.

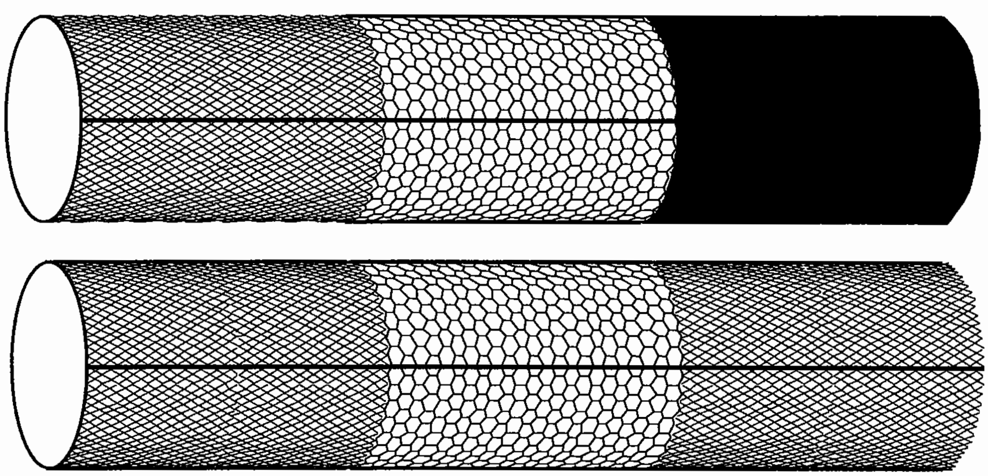


Figure 3. Example of the temperature profiles for hauls conducted in a) the spring and b) the fall

Figure 3a). Temperature profiles for hauls conducted in the spring

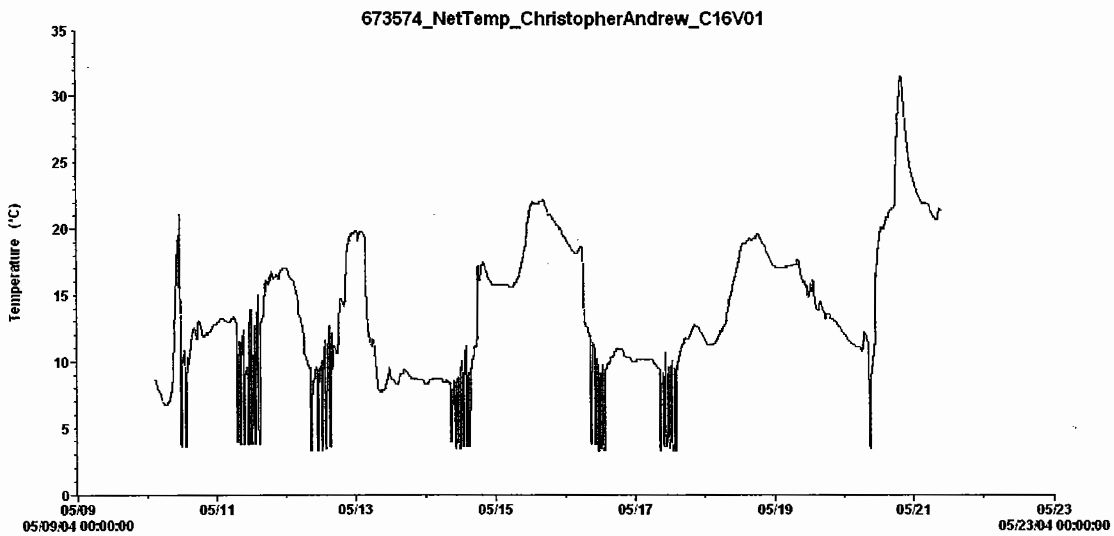


Figure 3b) Temperature profiles for hauls conducted in the fall

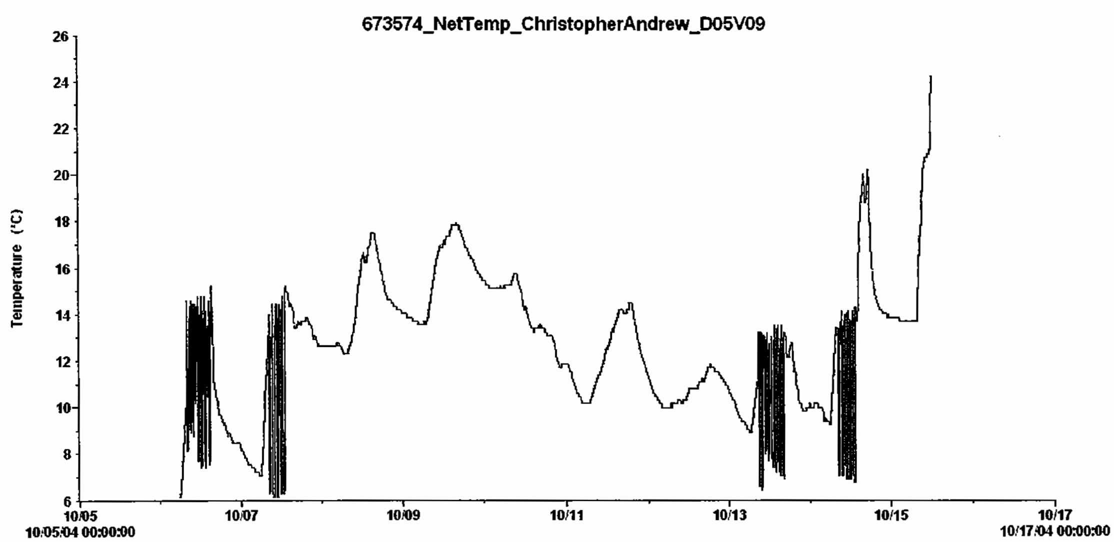


Figure 4. Comparison of the mean total, kept, discard, and discard of undersize fish in terms of weight (CPUE) for each window configuration for a) vessels (Christopher Andrew and North Star), for hauls conducted in the fall only and b) seasons, for hauls condcuted by the Christopher Andrew only. The p values for the Mann-Whitney non-parametric comparison for each window configuration are displayed above the bars. A value < 0.05 indicates statistical differences in haul weights.

Table 4 a)

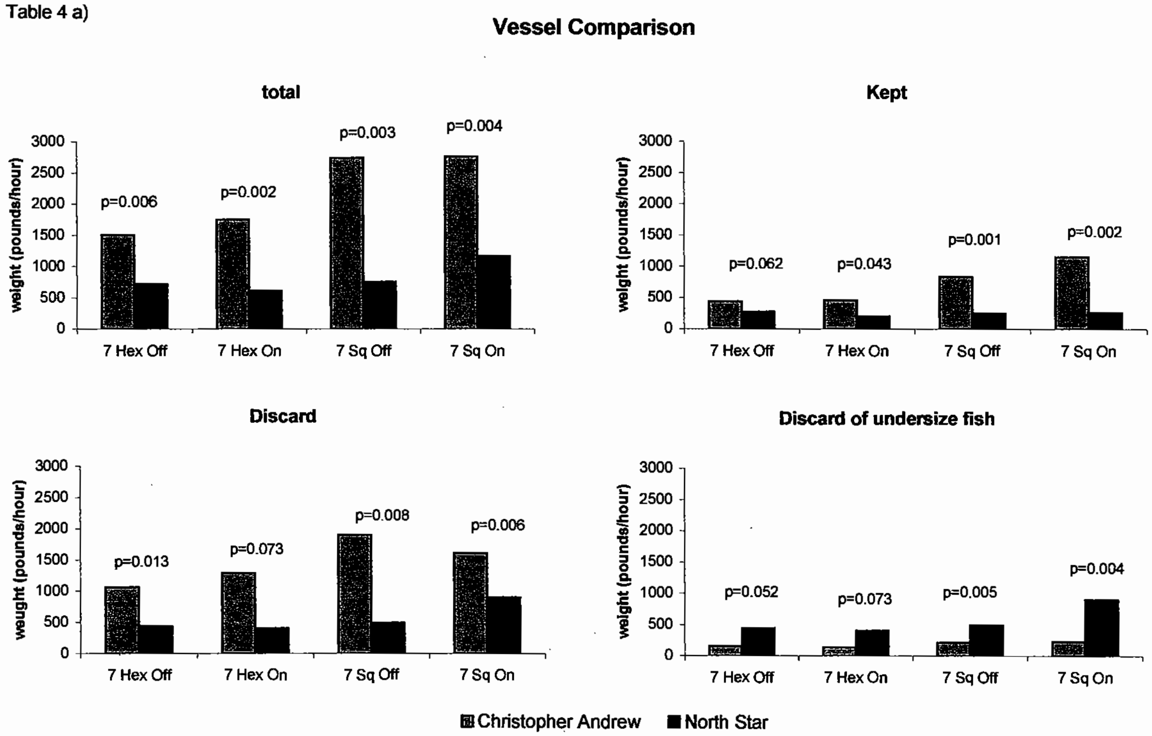


Table 4 b)

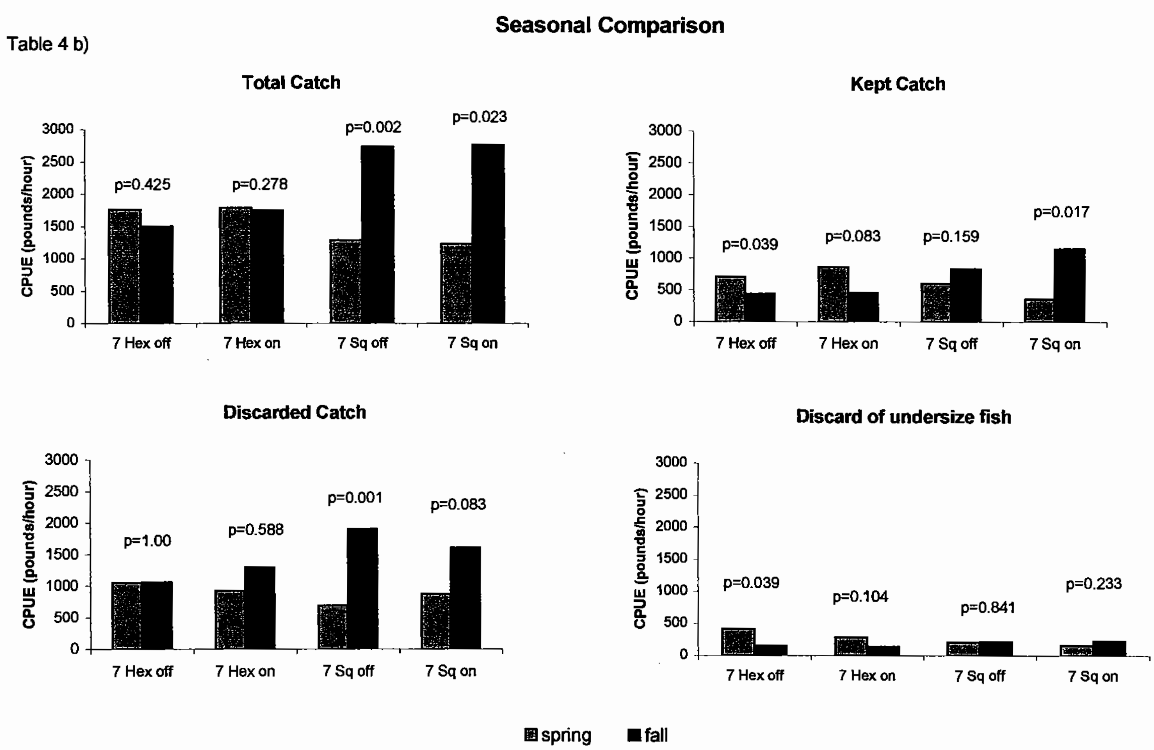


Figure 5. Mean weight (±standard error) for each window configuration for the total catch, kept catch, discarded catch and discard of undersize fish in terms of catch per unit effort (CPUE) for a) hauls conducted in the spring, b) hauls conducted in the fall by the Christopher Andrew, c) hauls conducted in the fall by the North star, d) all hauls conducted in the fall and e) all hauls pooled seasons and vessels.

Figure 5a) Spring (Christopher Andrew)

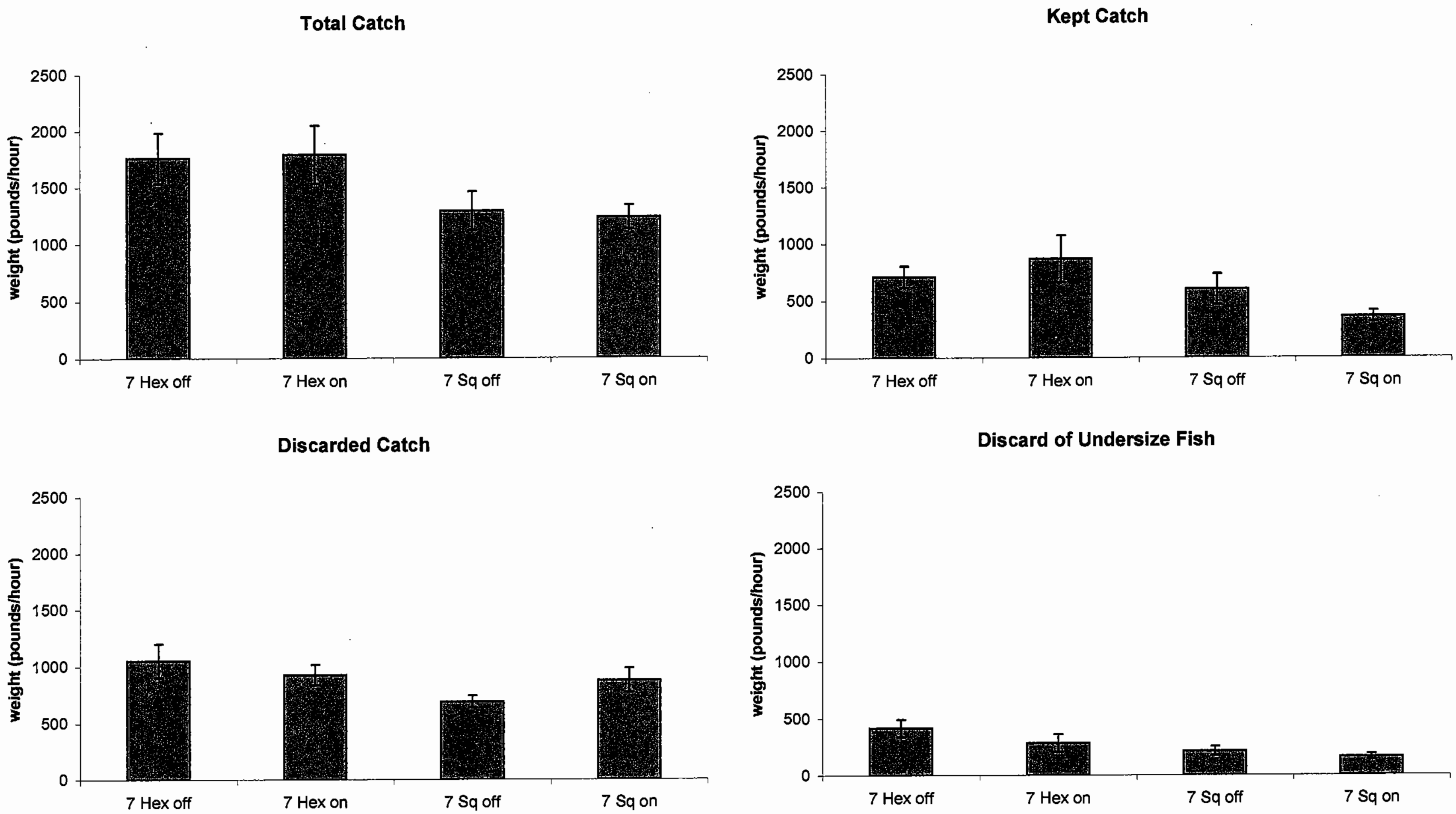


Figure 5b) Christopher Andrew in the Fall

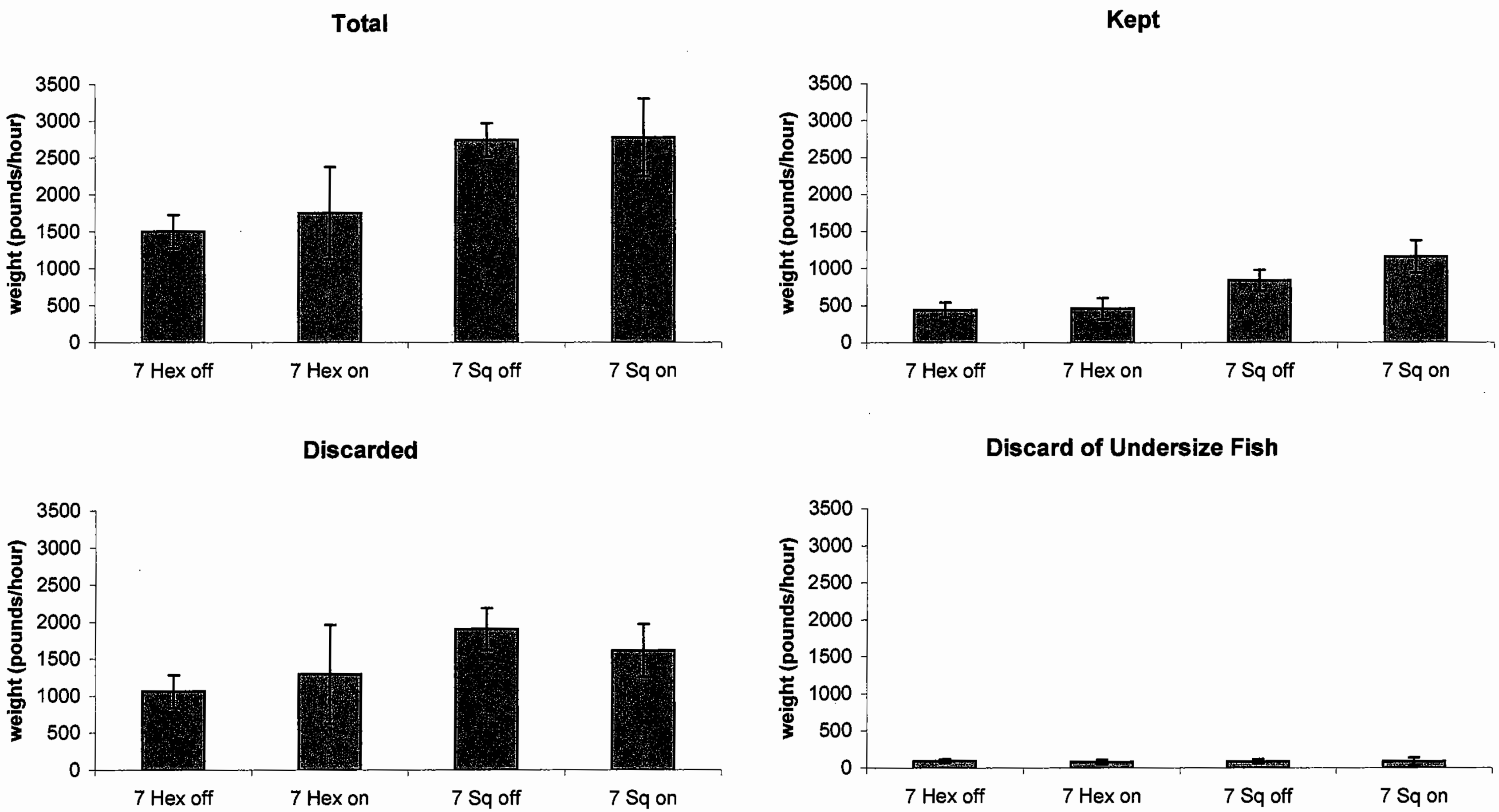


Figure 5c) North Star in the Fall

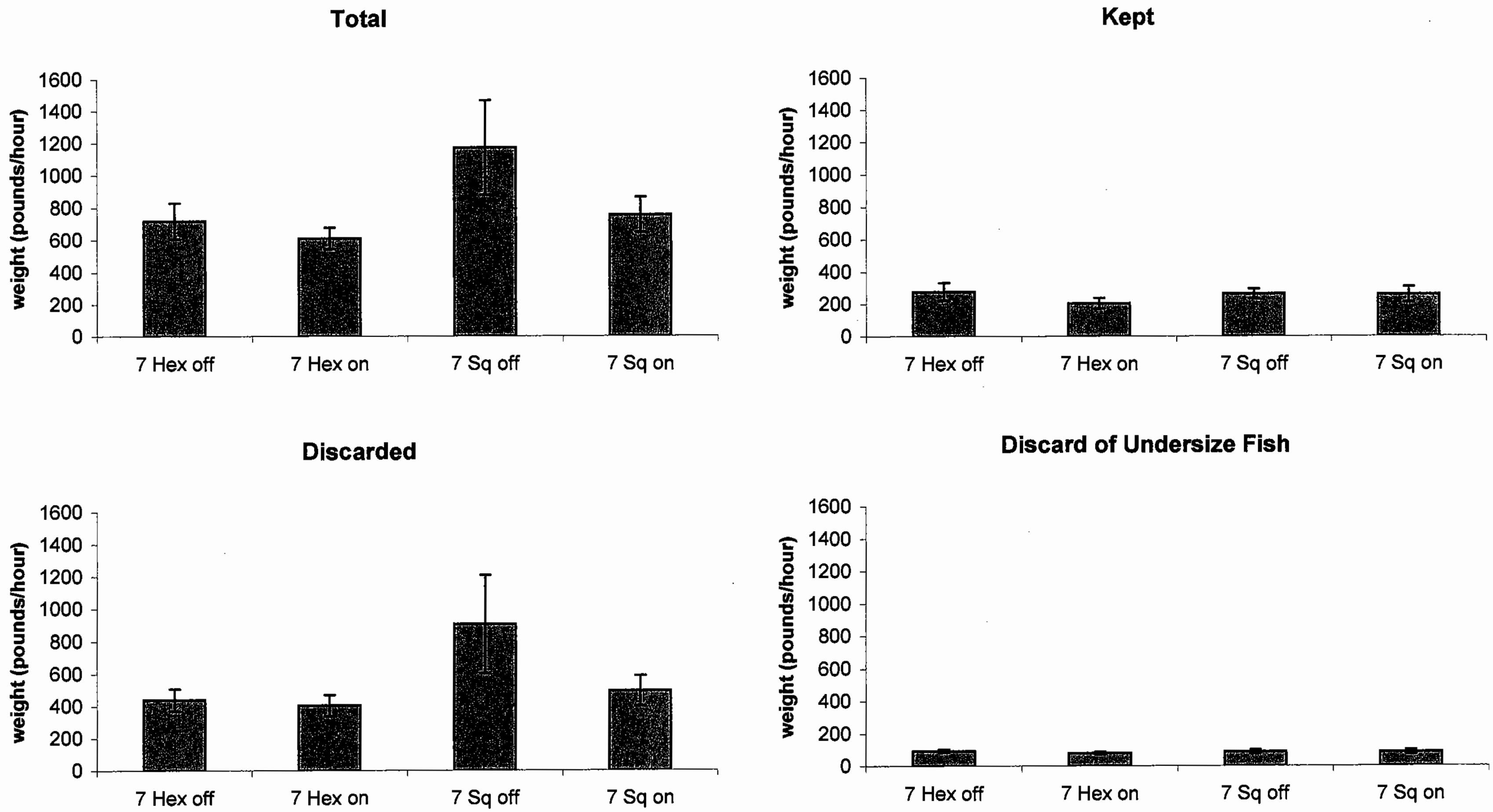


Figure 5d) Fall (pooled vessels)

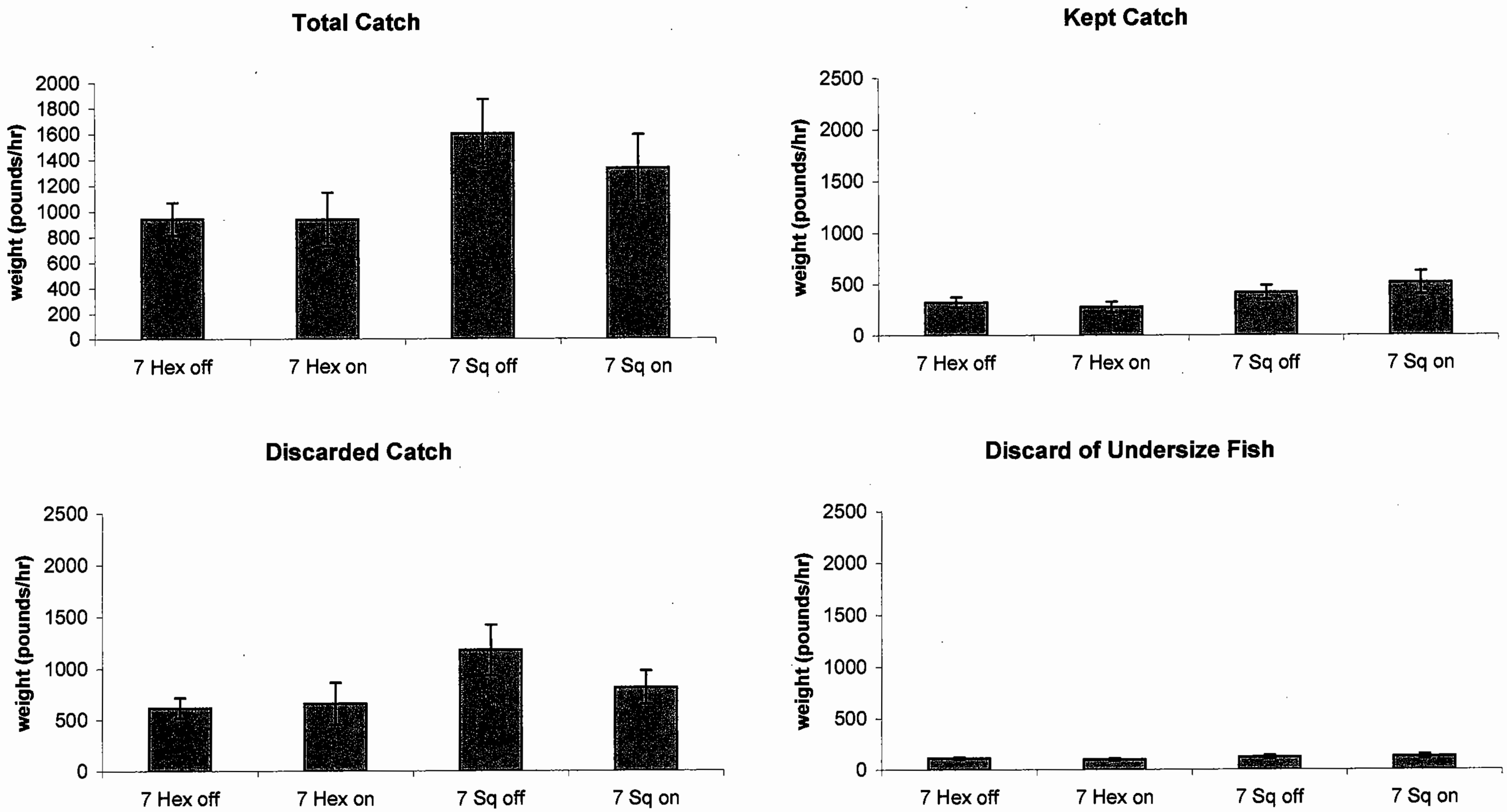


Figure 5e) All Hauls (pooled seasons and vessels)

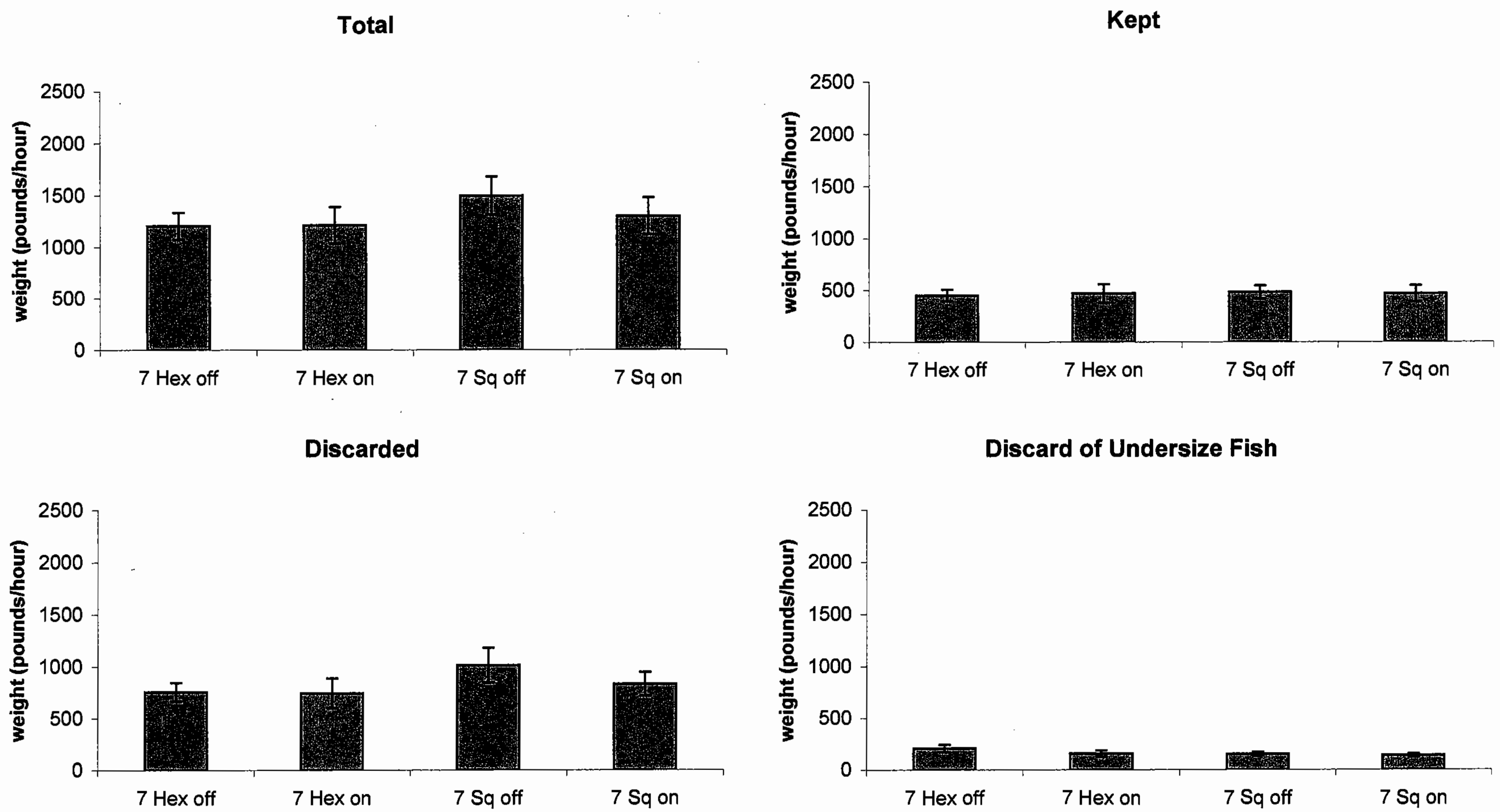


Figure 6. Mean number of individuals (±standard error) for the total, kept, discard and discard of undersize fish in term of catch per unit effort (CPUE) for a) hauls conducted in the spring, b) hauls conducted in the fall by the Christopher Andrew, c) hauls conducted in the fall by the North star, d) all hauls conducted in the fall and e) all hauls (pooled seasons and vessels)

Figure 6a) Spring (Christopher Andrew)

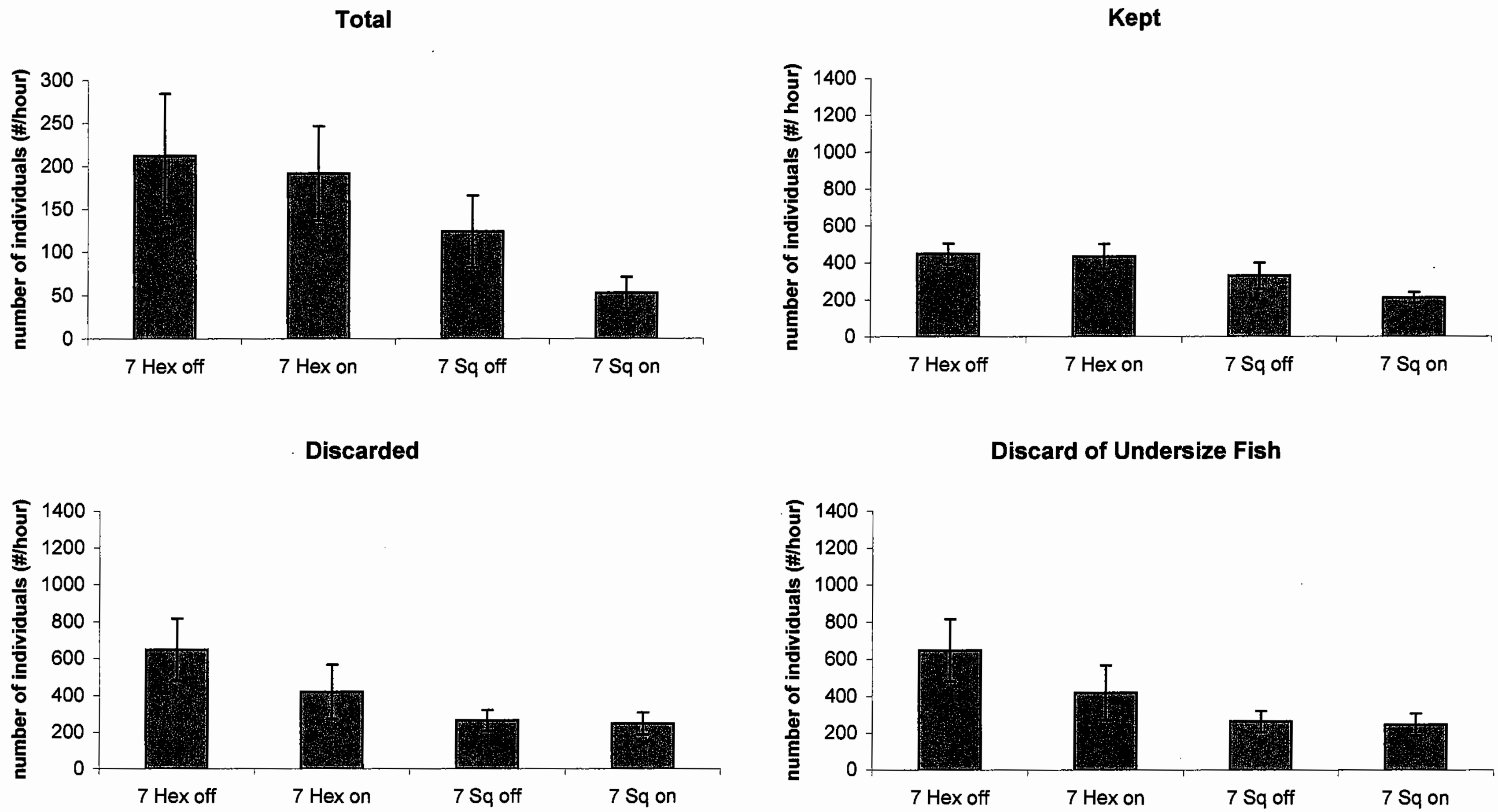


Figure 6b) Christopher Andrew in the Fall

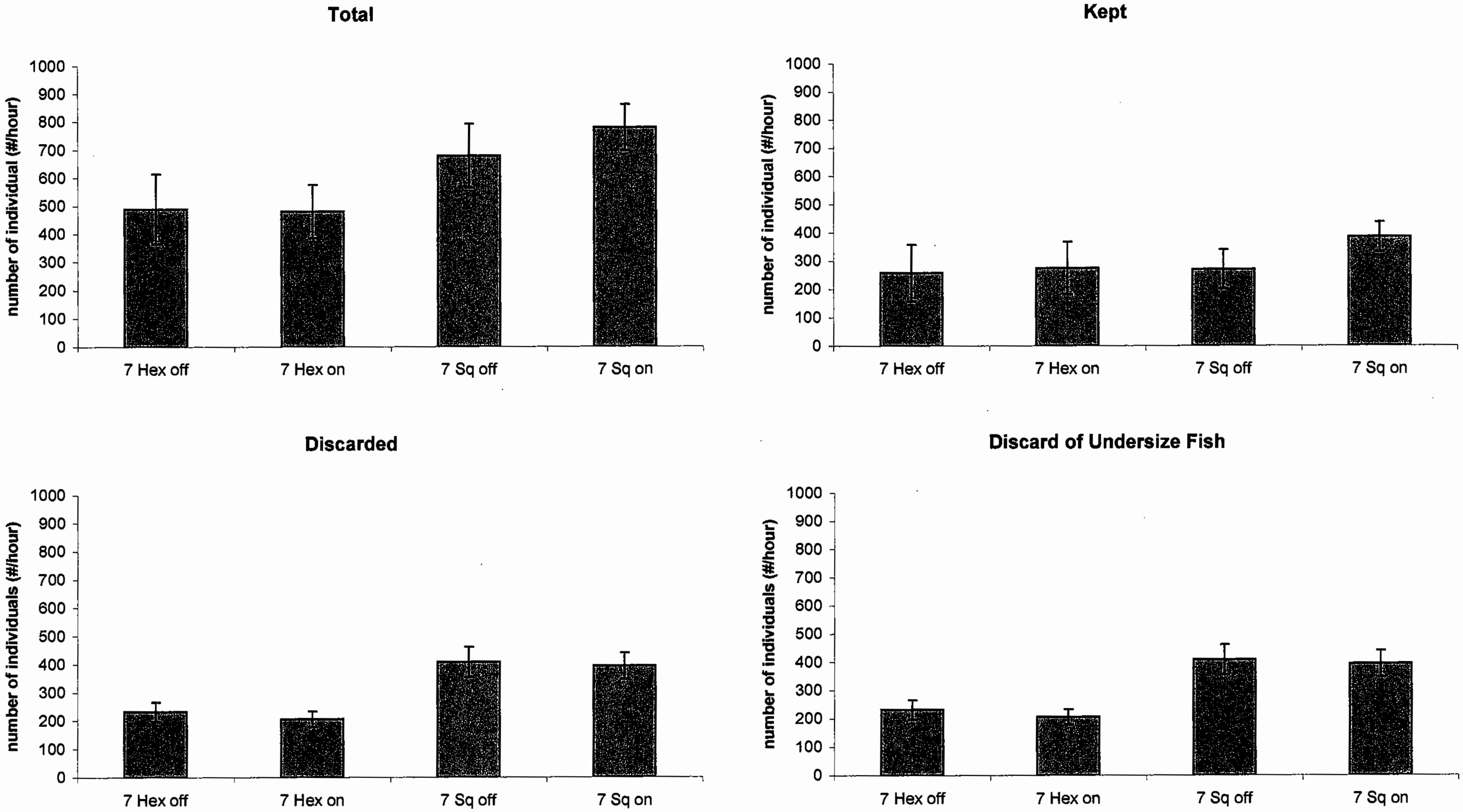


Figure 6c) North Star in the Fall

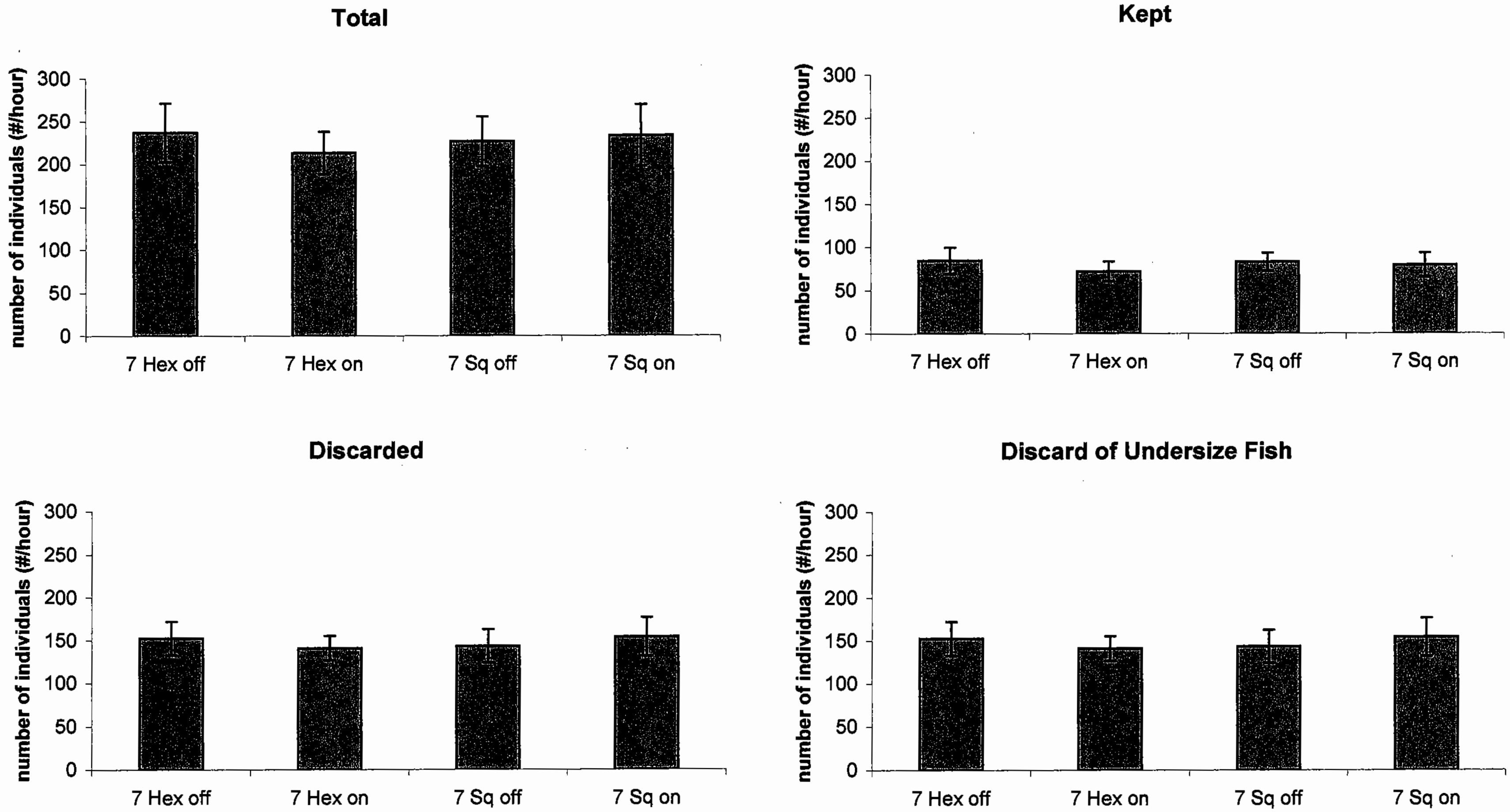


Figure 6d) Fall (pooled vessels)

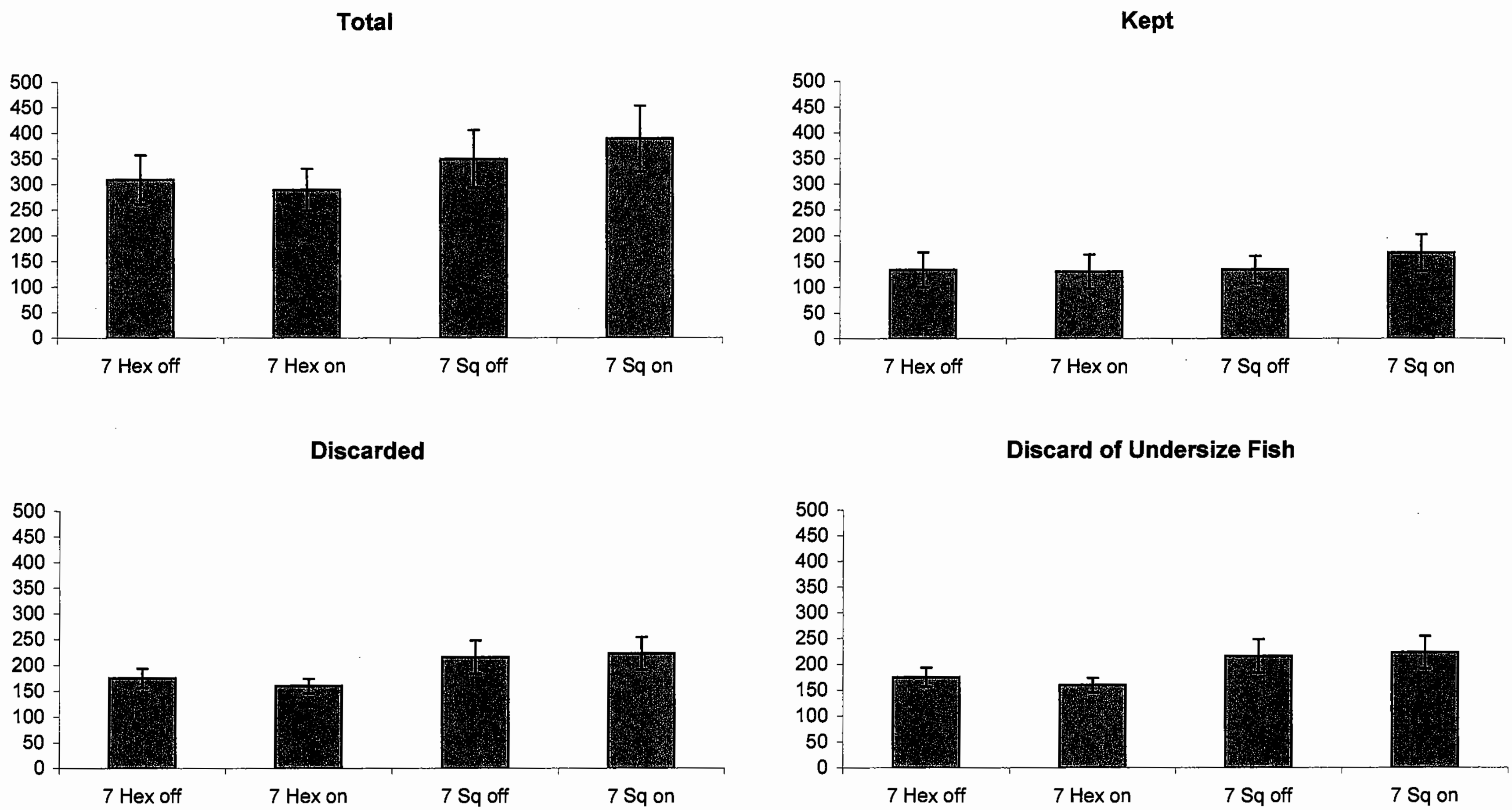


Figure 6e) All Hauls (pooled seasons and vessels)

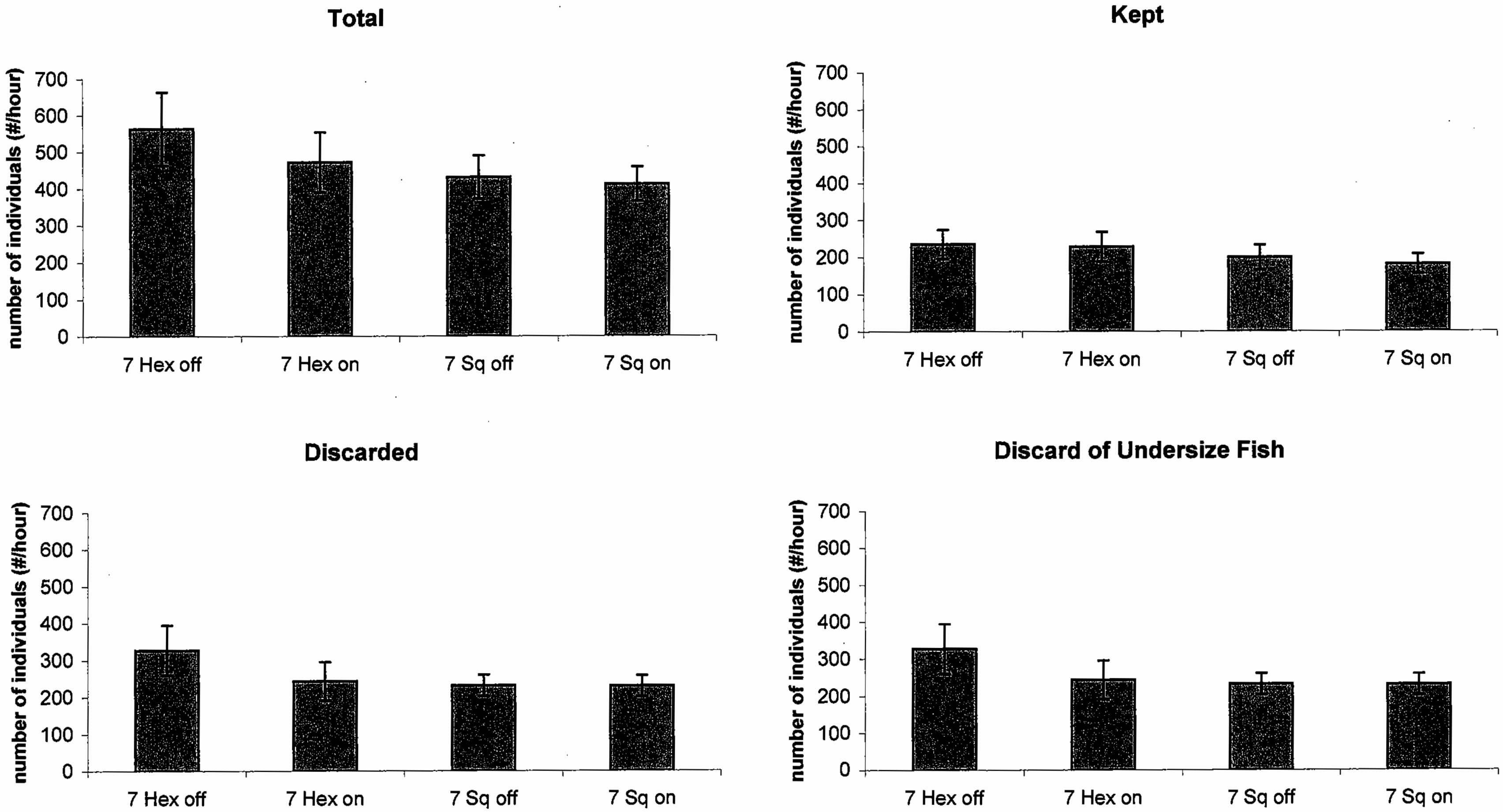


Figure 7. The proportion of the catch kept and discarded (where discard was broken down into discard of undersize fish and discard due to other reasons-named "other discard") by weight for a) hauls conducted in the spring, b) hauls conducted in the fall by the Christopher Andrew, c) hauls conducted in the fall by the North star, d) all hauls conducted in the fall and e) all hauls (pooled seasons and vessels)

Figure 7a) SPRING (Christopher Andrew)

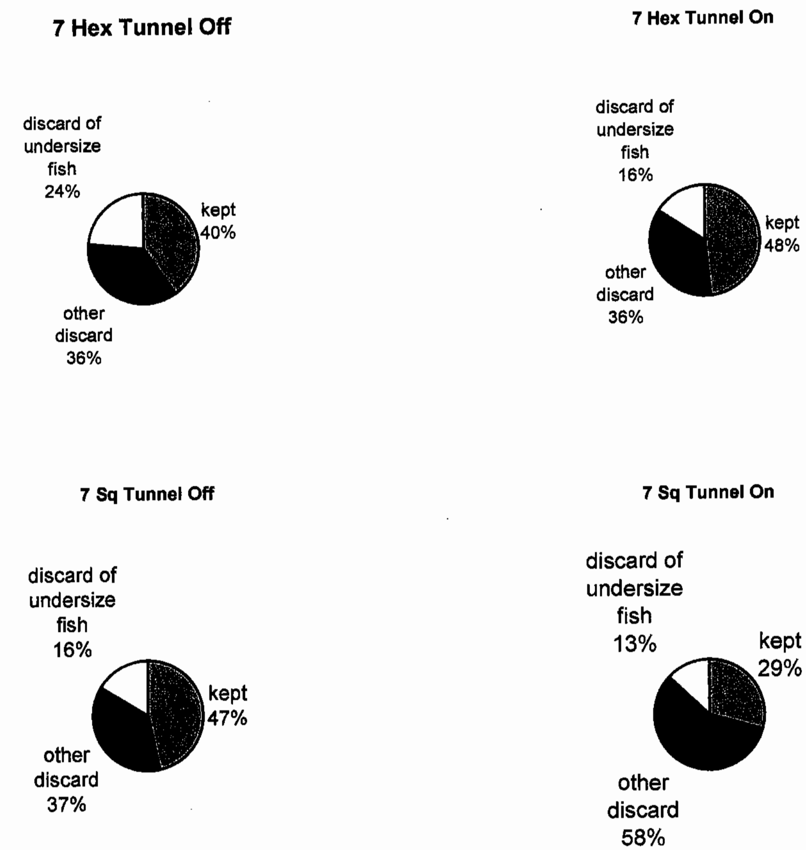


Figure 7b) Christopher Andrew in the Fall

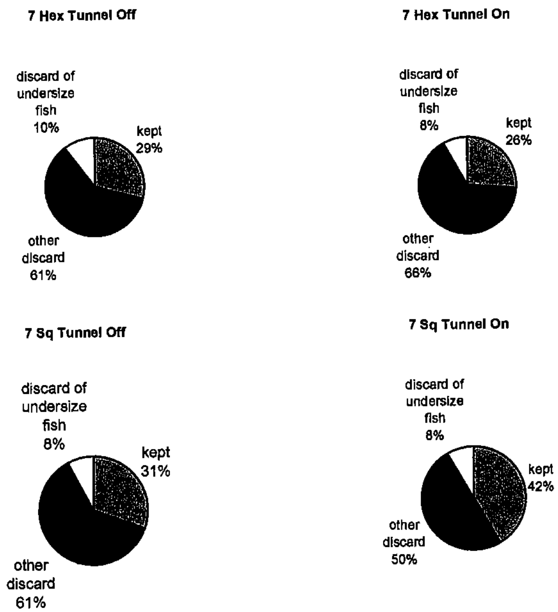


Figure 7c) North Star in the Fall

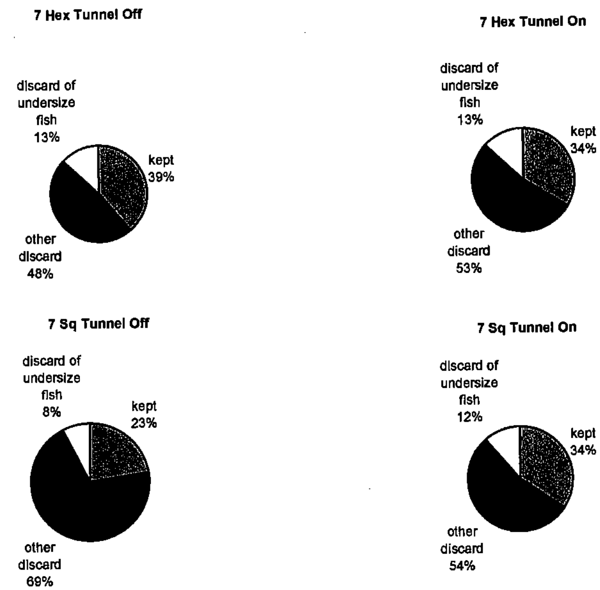


Figure 7d) Fall (pooled vessels)

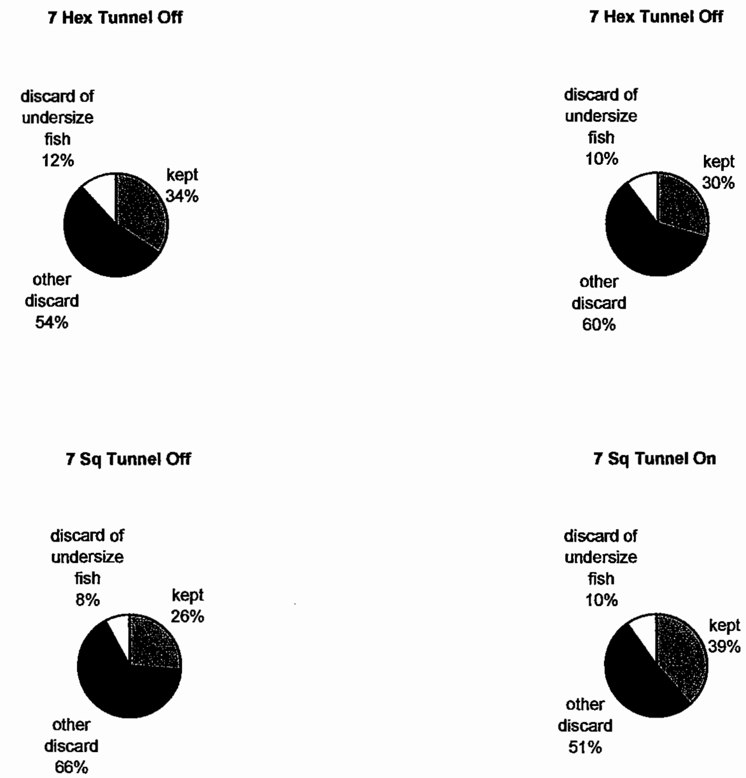
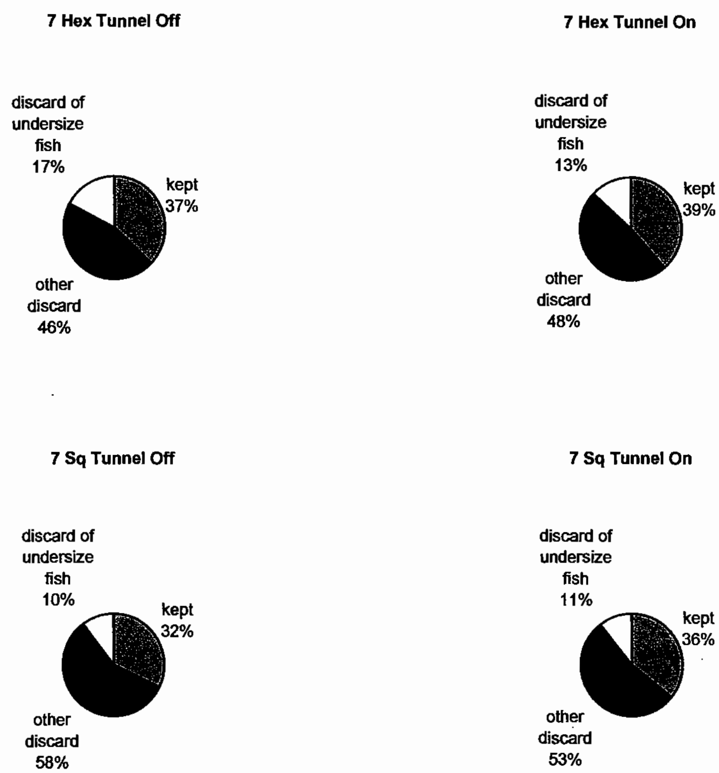


Figure 7e) All Hauls (pooled vessels and seasons)



Figrure 8. Pie charts displaying the composition of the catch for each window configuration in the a) spring, b) fall, and c) pooled seasons (all hauls).

Figure 8a. Catch Composition for all hauls conducted in the spring (Christopher Andrew)

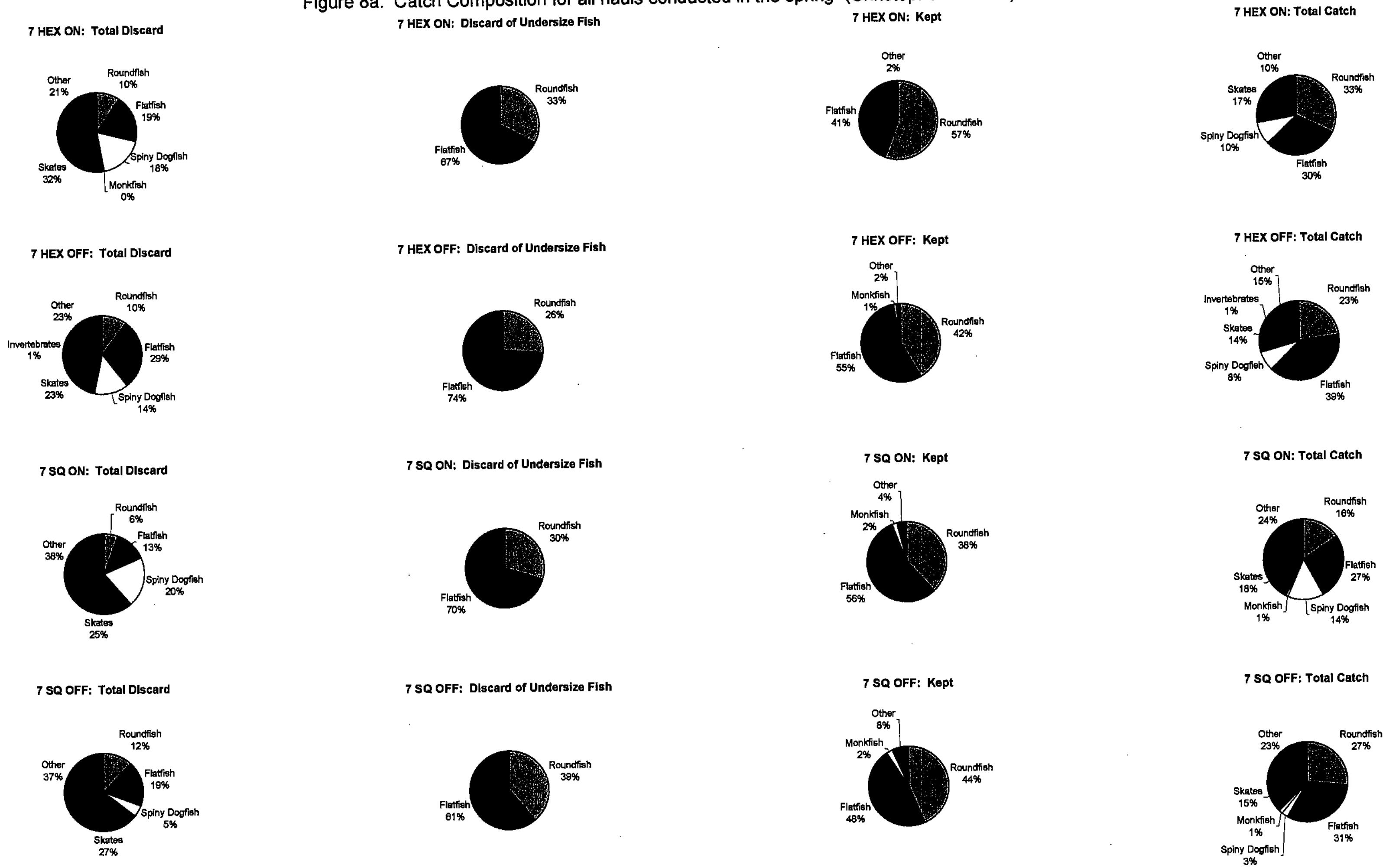


Figure 8b. Catch Composition for all hauls conducted in the fall (pooled vessels)

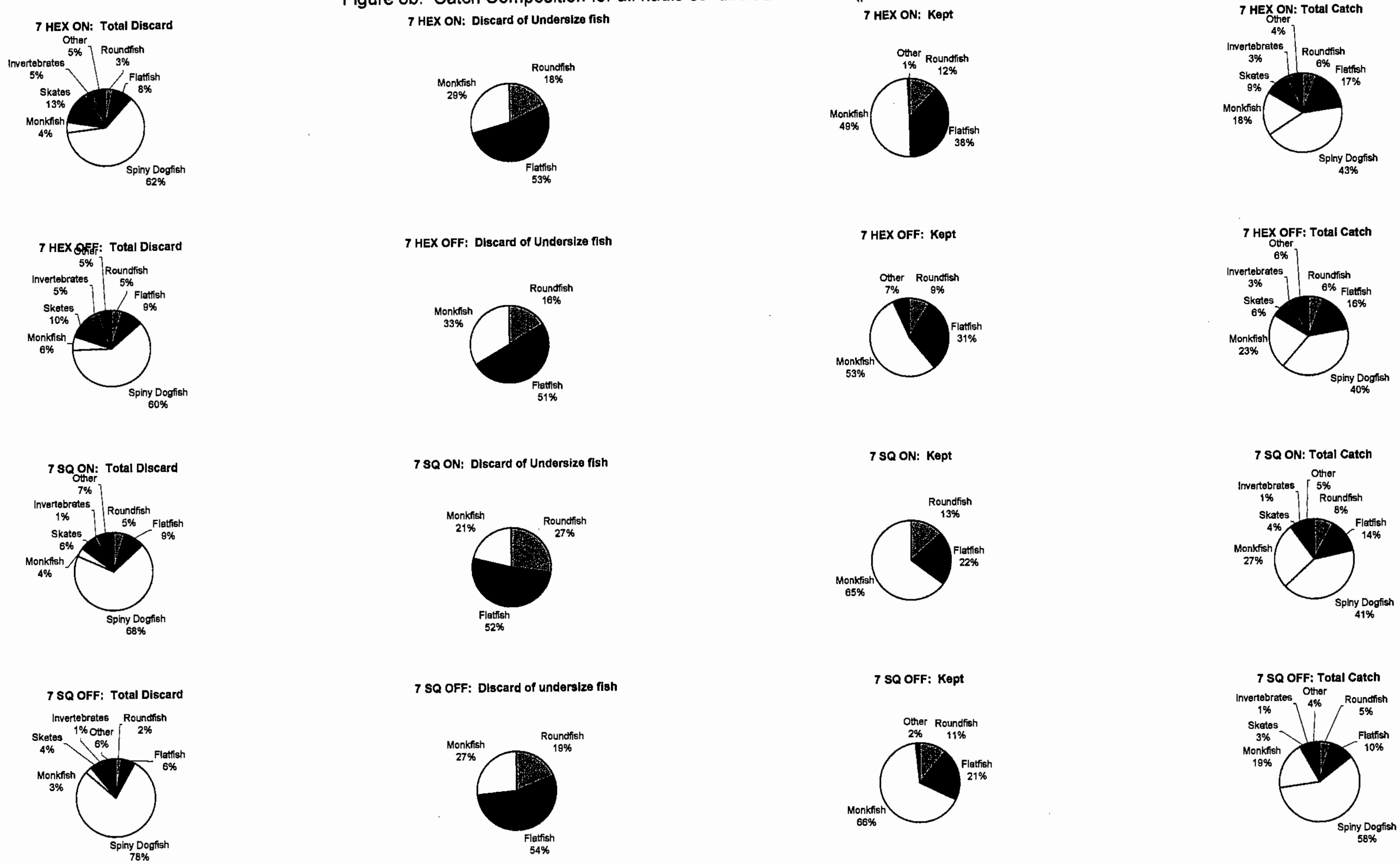


Figure 8c. Catch Composition for all hauls (pooled vessels and seasons)

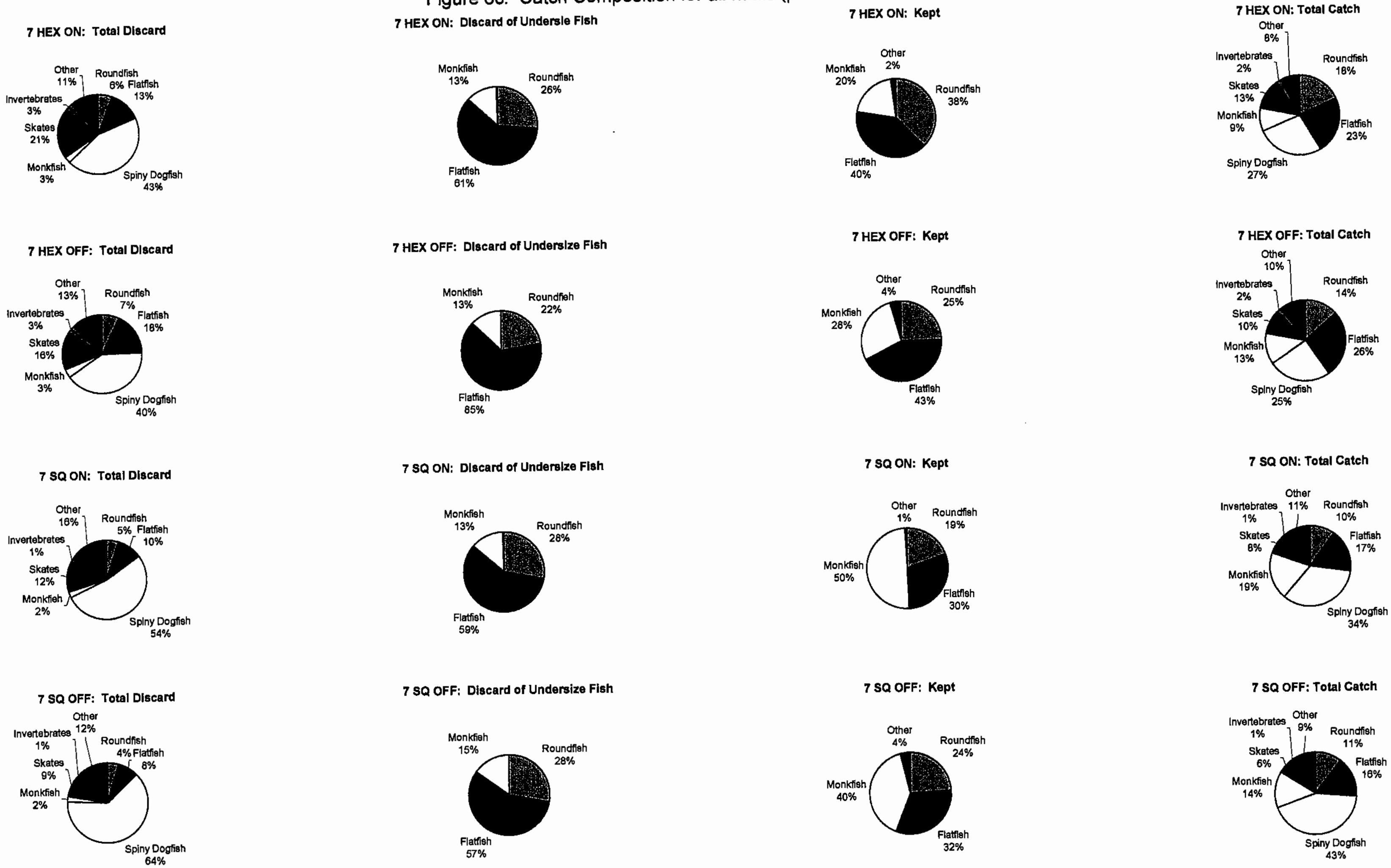
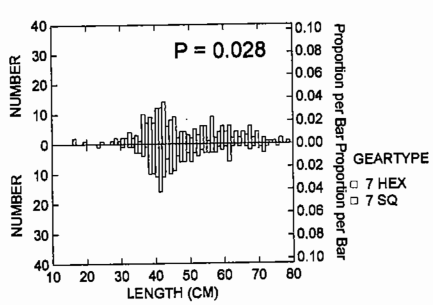


Figure 9. Window mesh comparisons of length frequancy distributions. Length frequency distributions comparing the populations of fish caught by the 7" hex mesh widow and the 7" sq mesh window. Comparisons were completed between 7" hex and 7" sq both with the tunnel on and between the 7" hex and 7" sq both with the tunnel off for each fish. In each graph, the fish from the 7" hex are on the top and fish from the 7" sq are on the bottom. P value results from the two sample K-S test are listed next to each comparative figure. A p value of 0.05 or less indicates significant differences in the populations of fish sampled by the two mesh types (hex and sq).

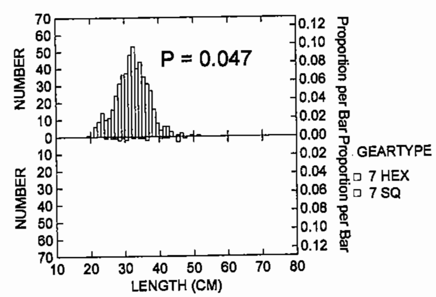
Comparisons between mesh types were completed for hauls conducted in the spring, for hauls conducted in the fall by the Christopher Andrew, the North Star, and both vessels pooled together, and for all hauls from both seasons and vessels pooled together.

LFDs comparing mesh type for the spring hauls by the Christopher Andrew with the tunnel off

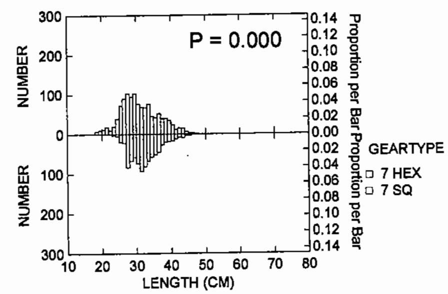
Cod



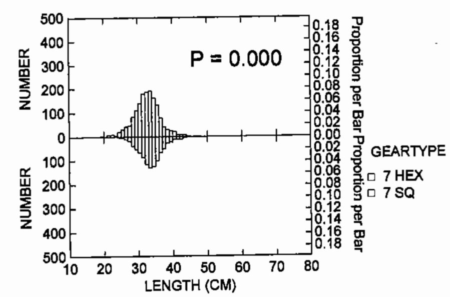
Dab (American Plaice)



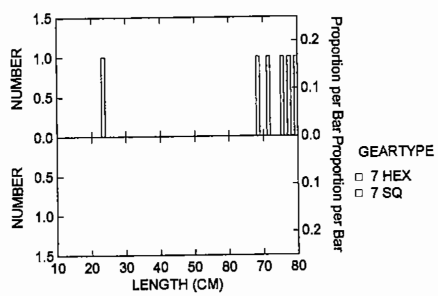
Winter Flounder



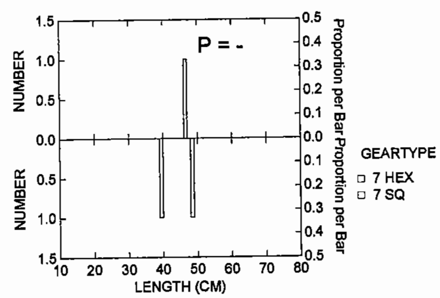
Yellowtail Flounder



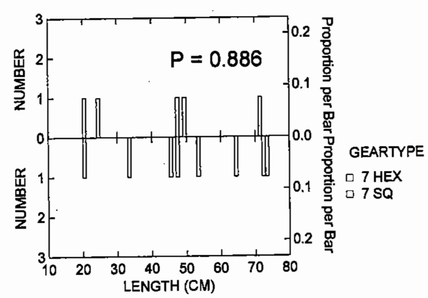
Pollock



Witch Flounder (Grey Sole)



Monkfish



Haddock

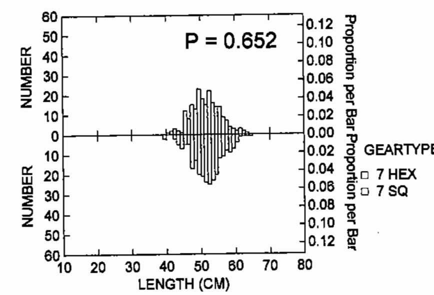


Figure 9. LFDs comparing mesh type for the spring hauls by the Christopher Andrew with the tunnel on

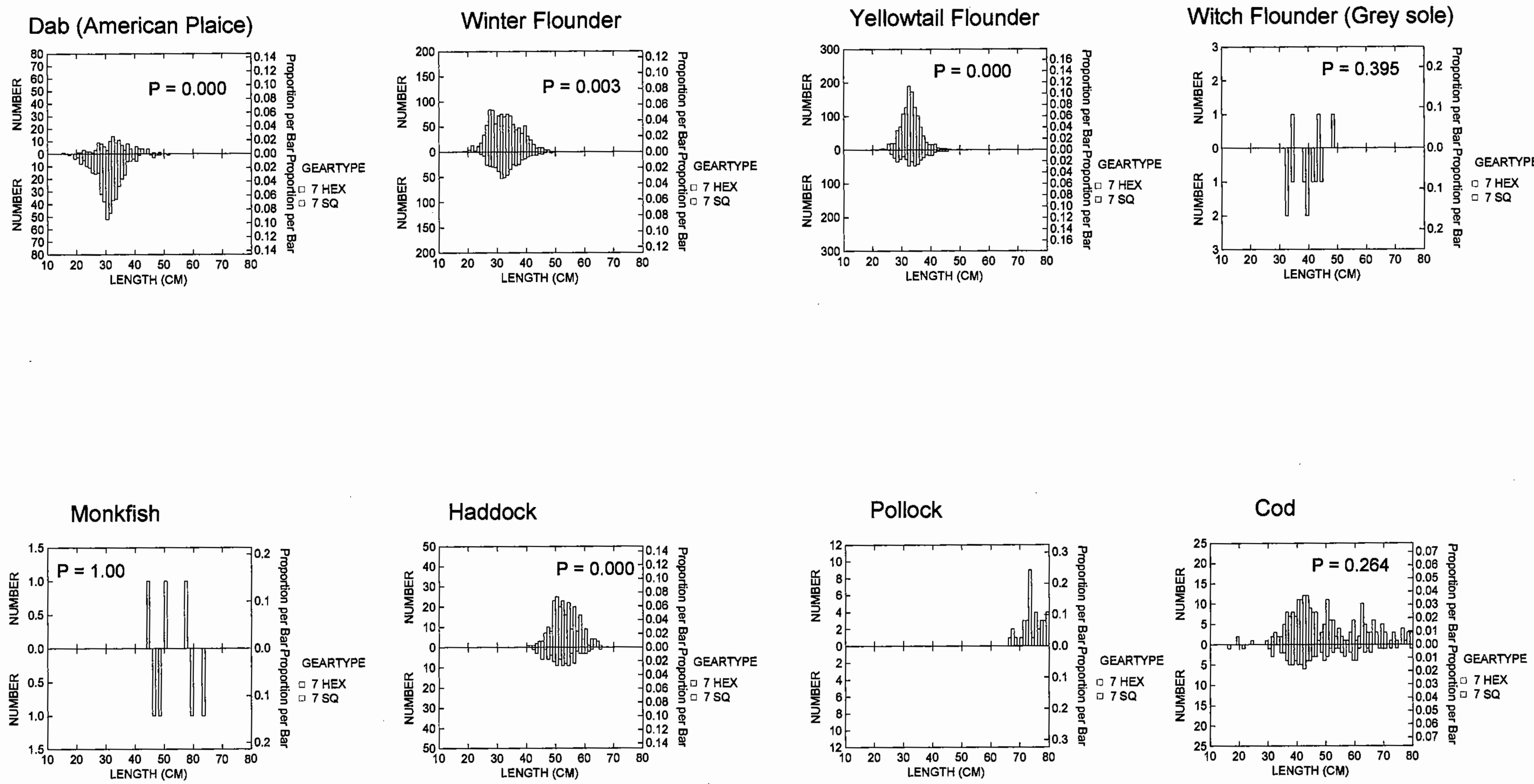


Figure 9. LFDs comparing mesh type for fall hauls by the Christopher Andrew with the tunnel off

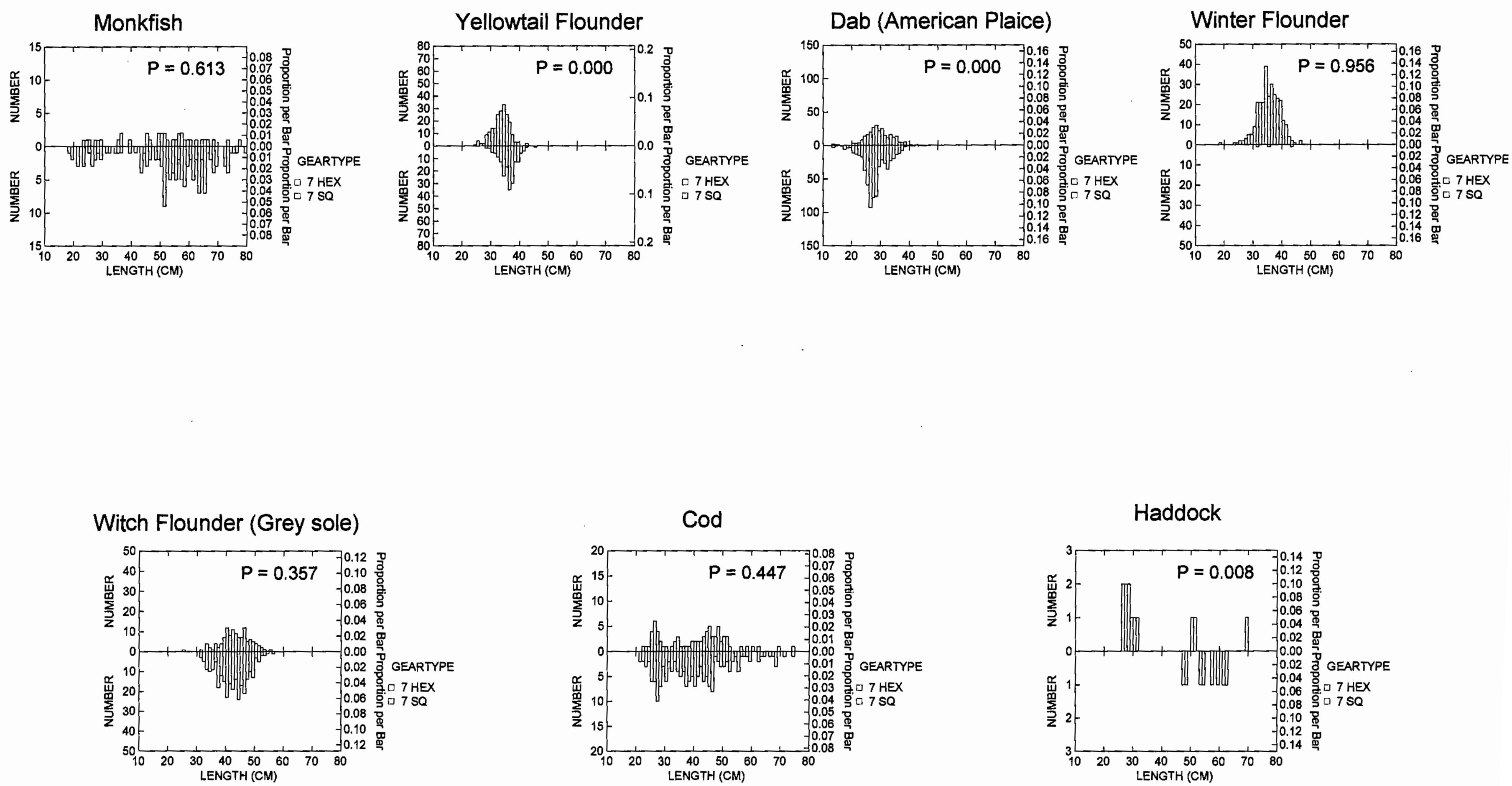


Figure 9. LFDs comparing mesh type for fall hauls by the North Star with the tunnel off

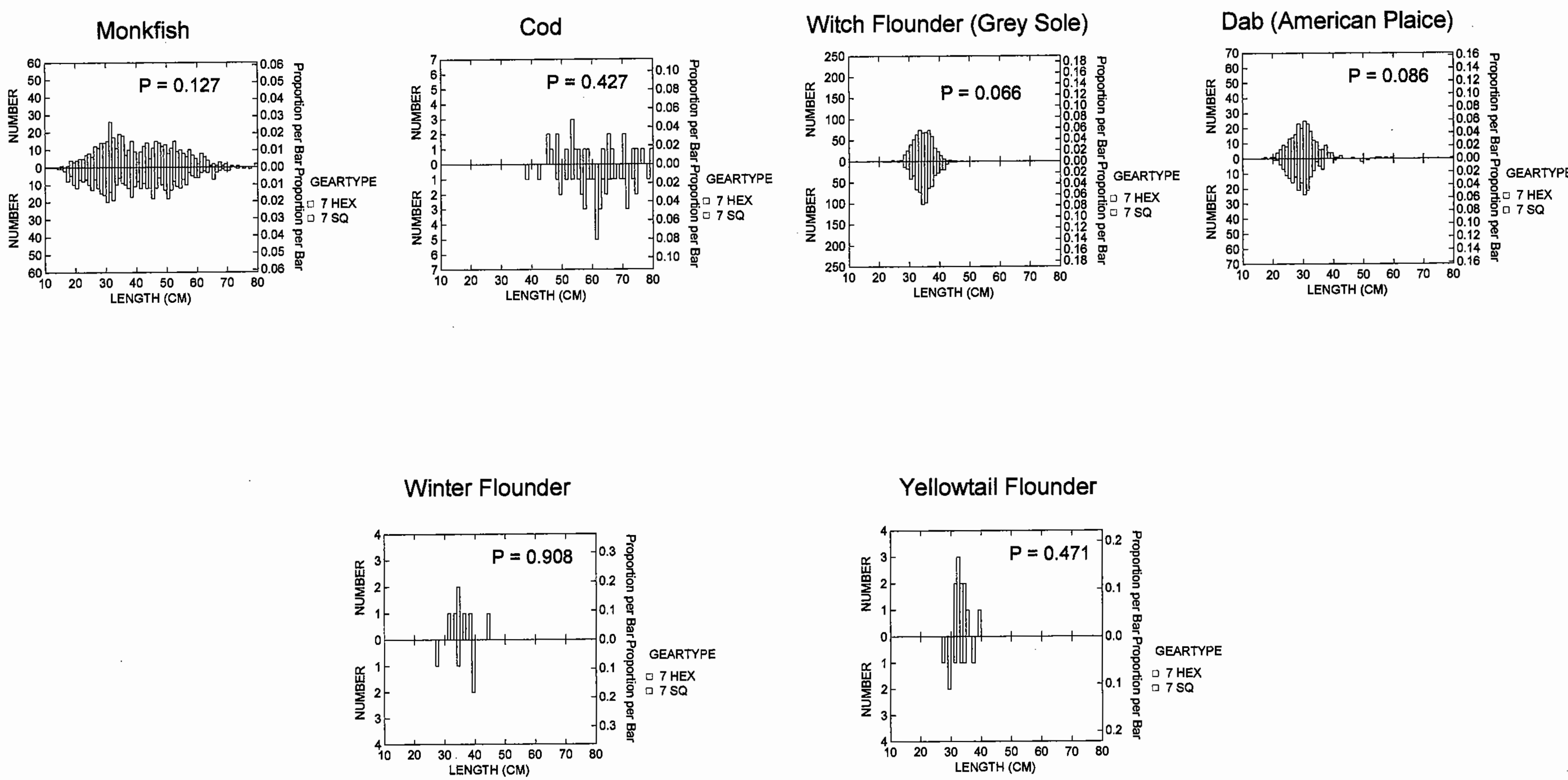


Figure 9. LFDs comparing mesh type for fall hauls by the North Star with the tunnel on

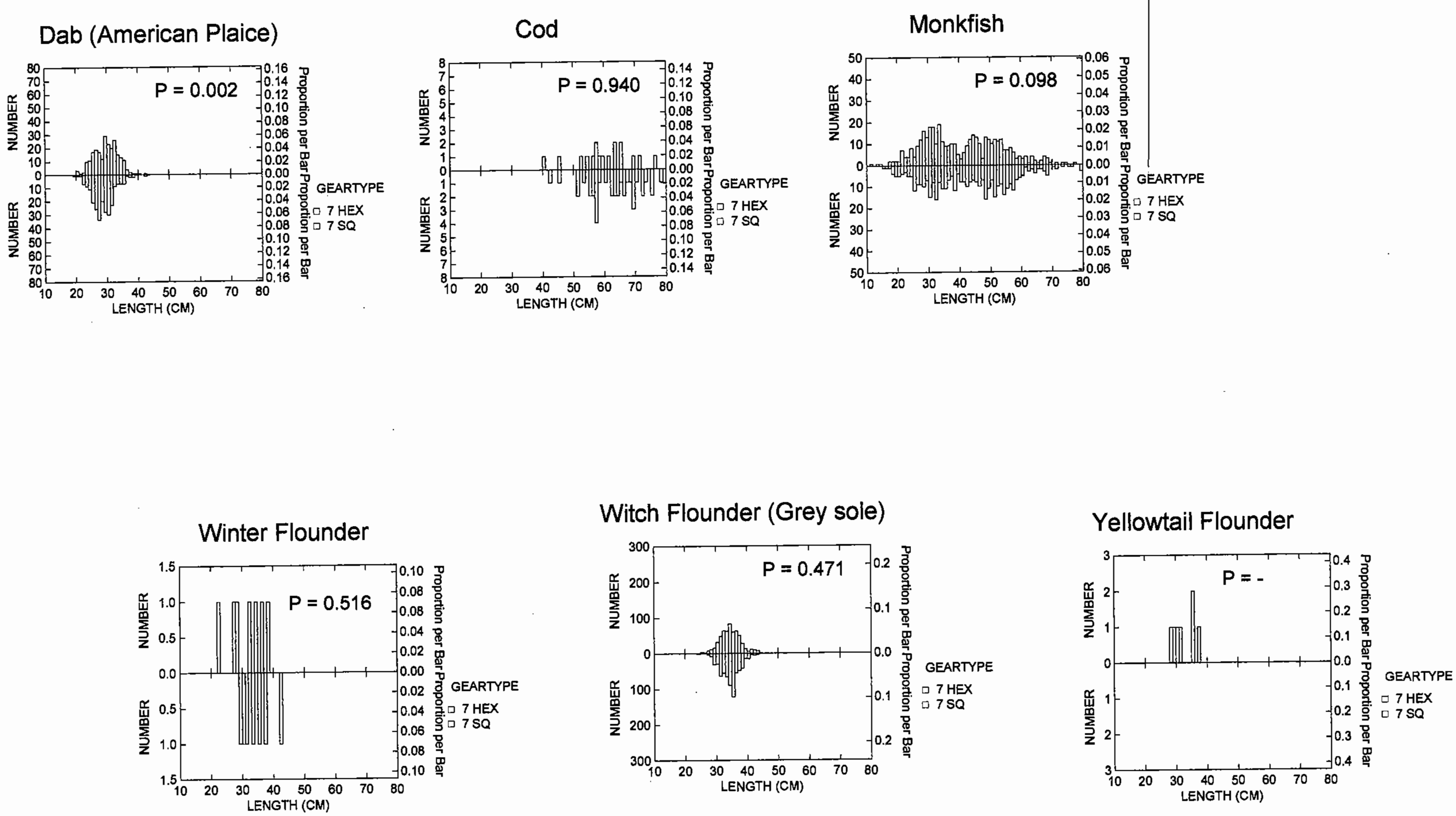


Figure 9. LFDs comparing mesh type for all hauls completed in the fall with the tunnel off

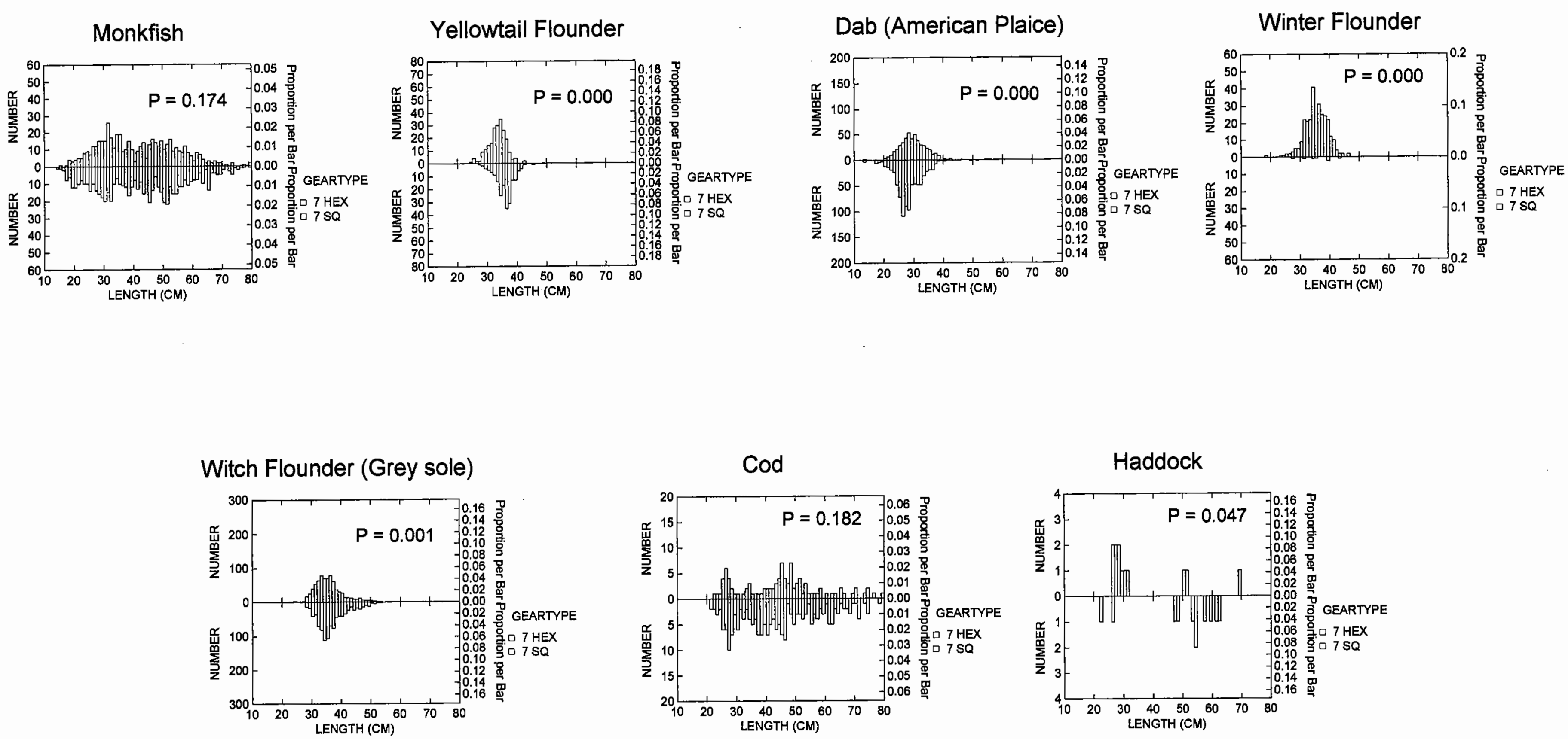


Figure 9. LFDs comparing mesh type for all hauls completed in the fall with the tunnel on

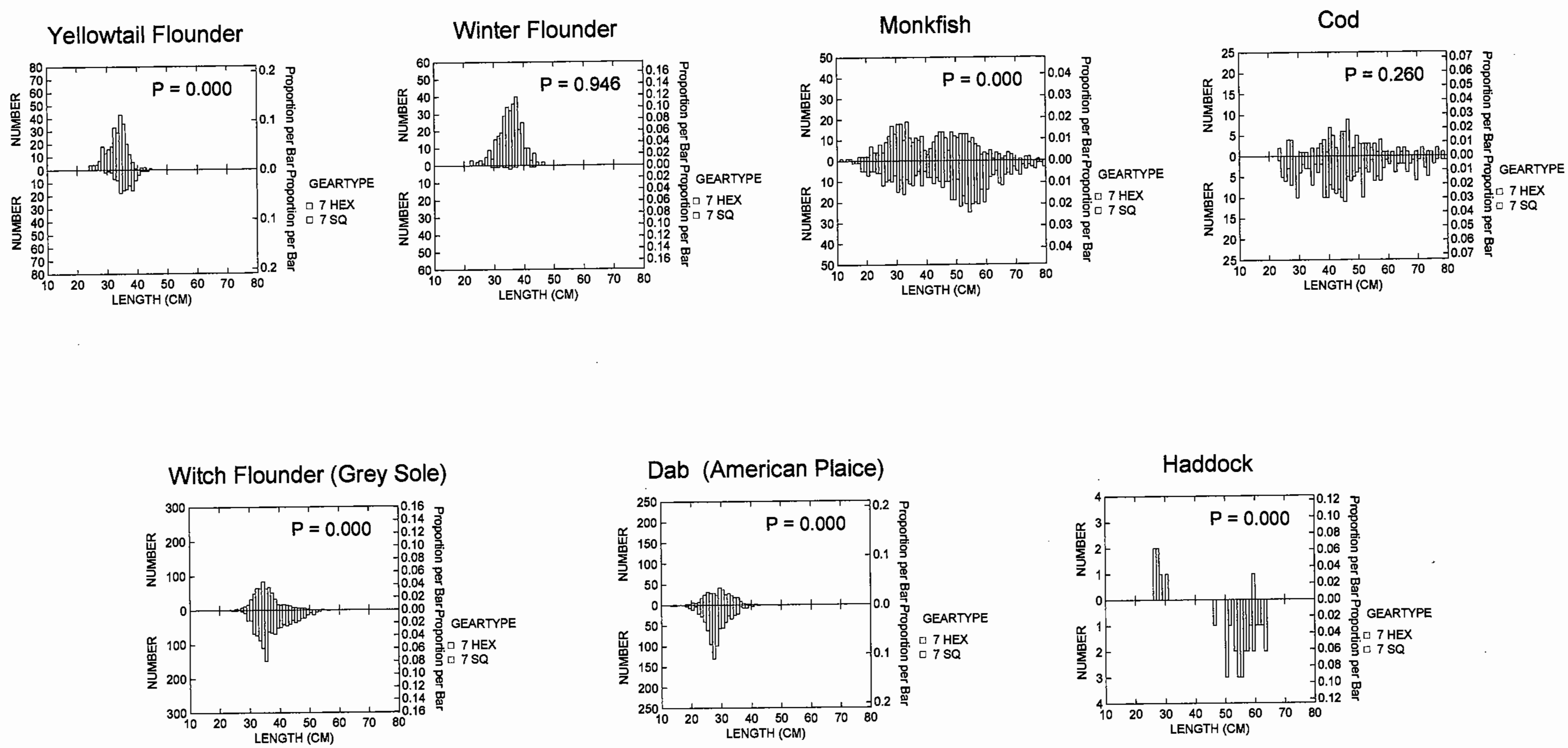


Figure 9. LFDs comparing mesh type for all hauls with the tunnel off

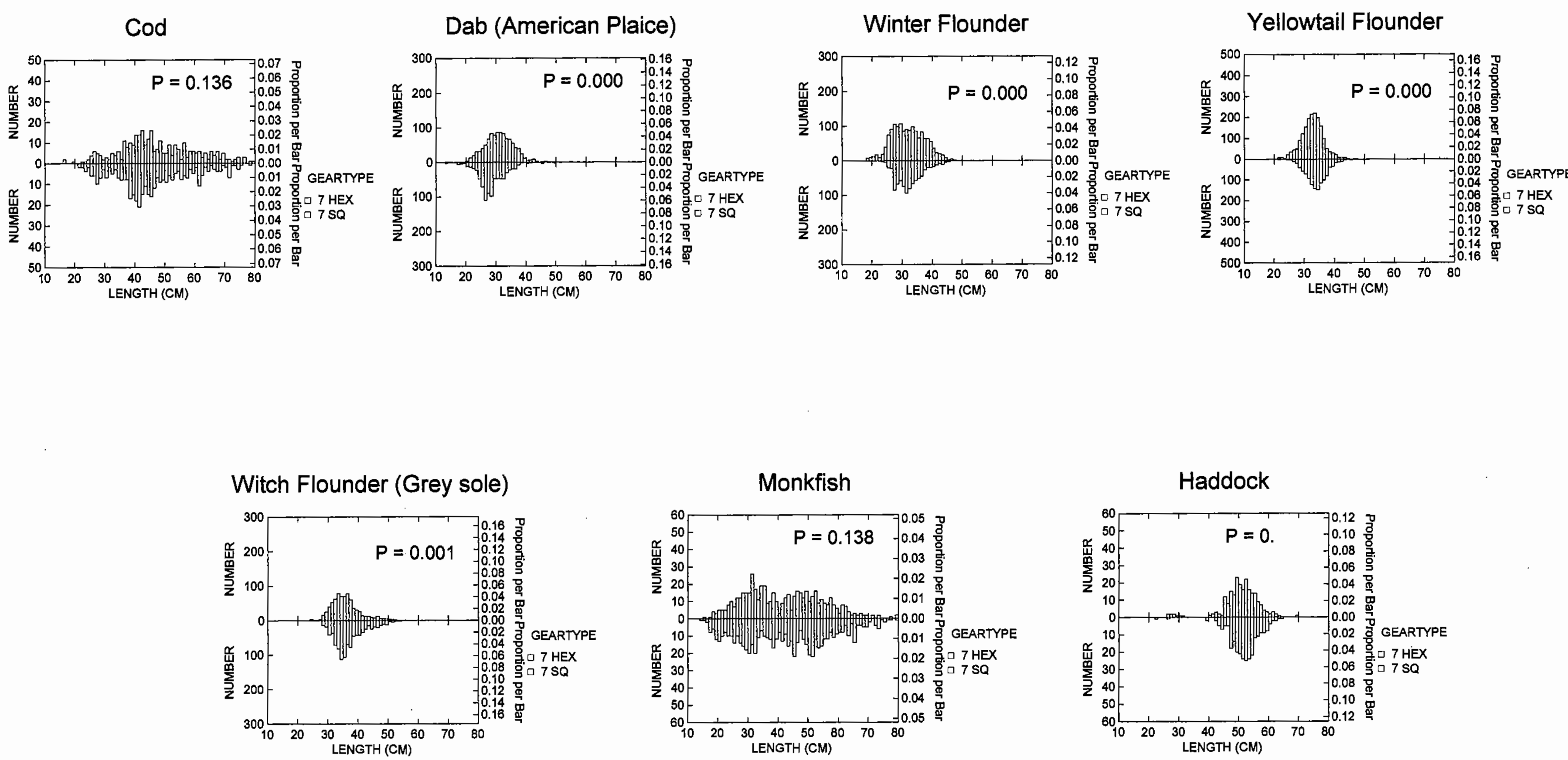


Figure 9. LFDs comparing mesh type for all hauls with the tunnel on

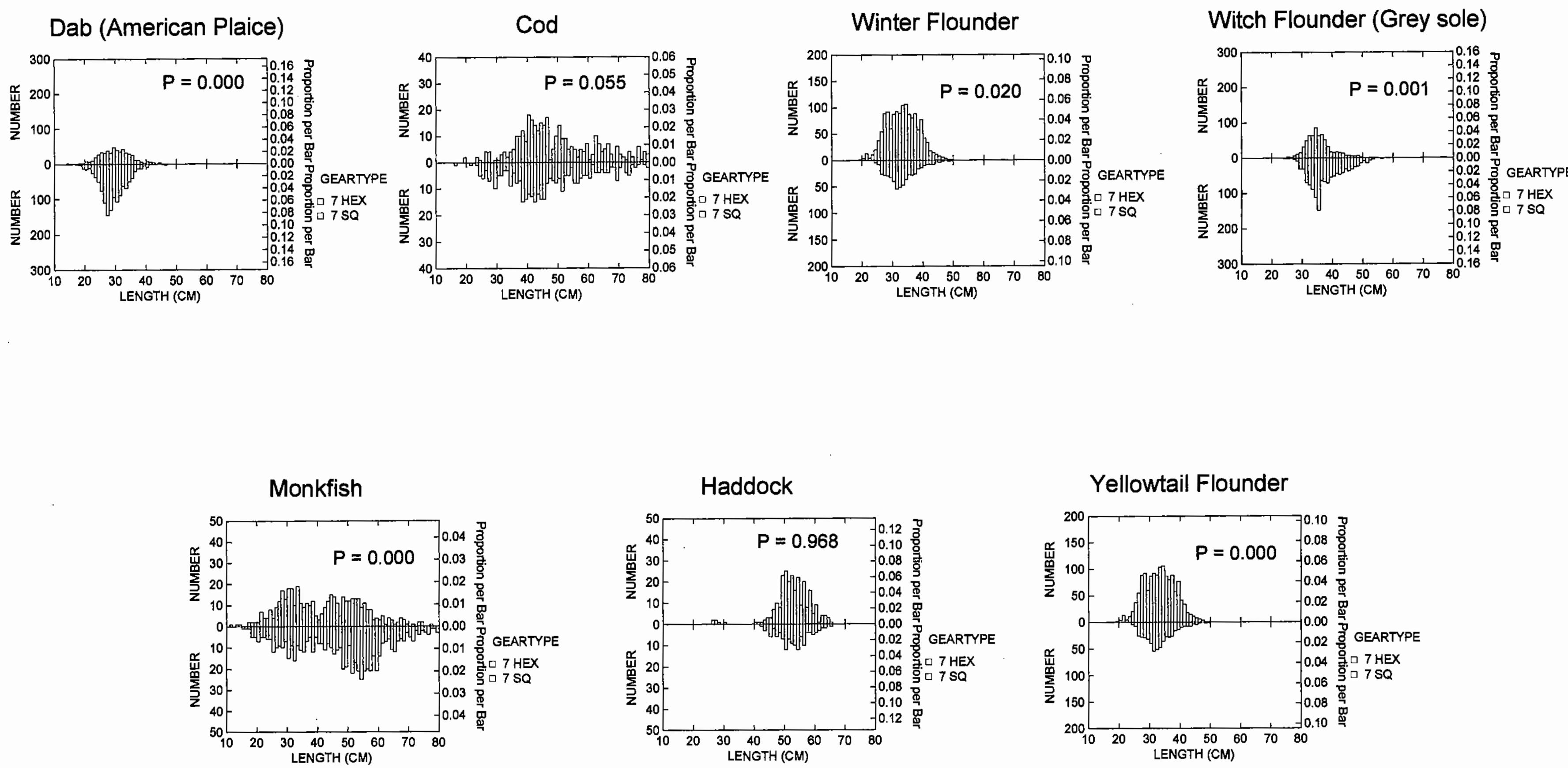


Figure 10. Length frequency distributions comparing the presence and absence of black tunnel visual stimulus. Length frequency distributions comparing the populations of fish caught by hauls conducted with the tunnel off to hauls conducted with the tunnel on. Comparisons were completed between the presence and absence of the black tunnel for the 7" hex and for the 7" sq windows. In each graph, the fish from hauls conducted without the black tunnel are on the top and the fish from the hauls with the black tunnel are on the bottom. P value results from the two sample K-S test are listed next to each comparative figure. A p value of 0.05 or less indicates significant differences in the populations of fish sampled with and without the black tunnel visual stimulus.

Comparisons between hauls with the black tunnel off and hauls with the black tunnel on were completed for hauls conducted in the spring, for hauls conducted in the fall by the Christopher Andrew, the North Star, and both vessels pooled together, and for all hauls from both seasons and vessels pooled together.

LFDs comparing presence and absence of black tunnel in the spring for hex mesh windows

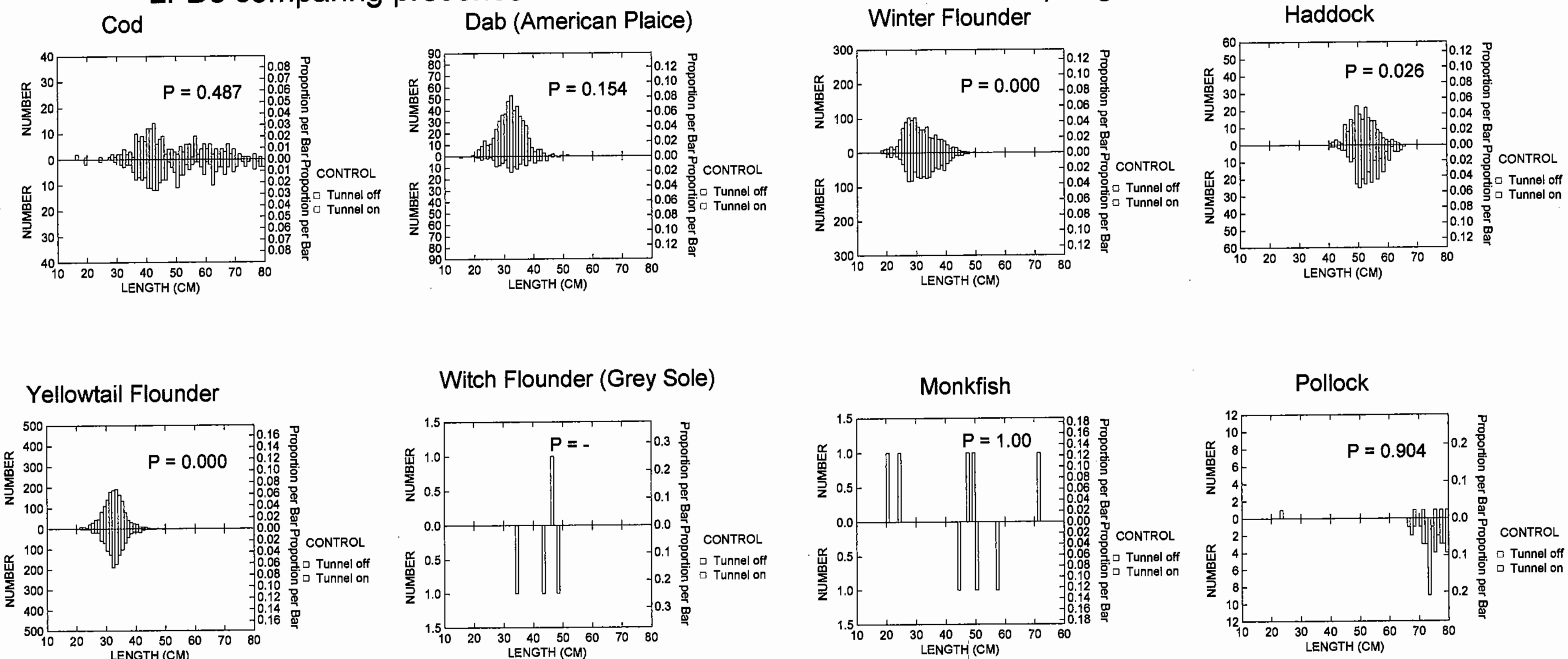


Figure 10. LFDs comparing presence and absence of black tunnel in the spring for sq mesh windows

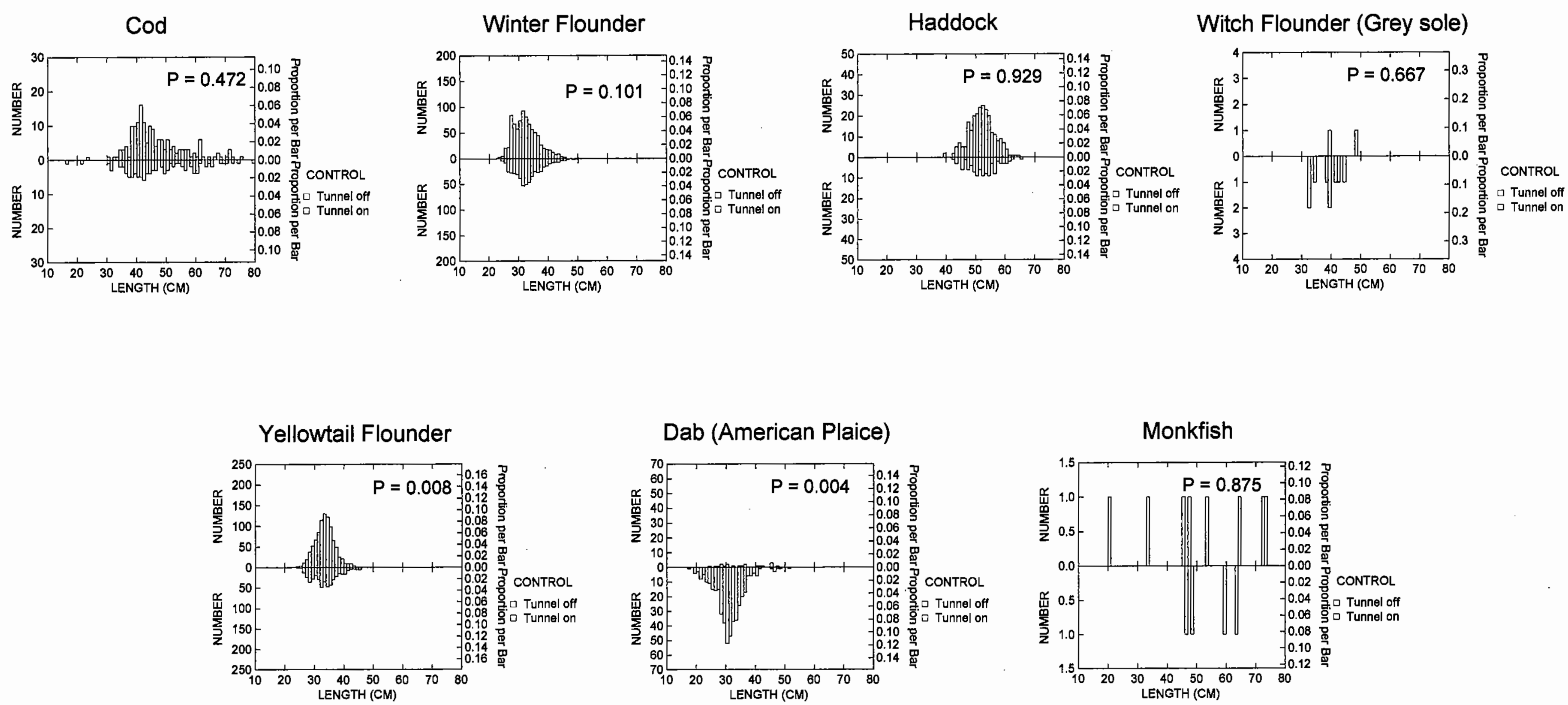


Figure 10. LFDs comparing presence and absence of black tunnel in the fall by the Christopher Andrew for hex mesh windows

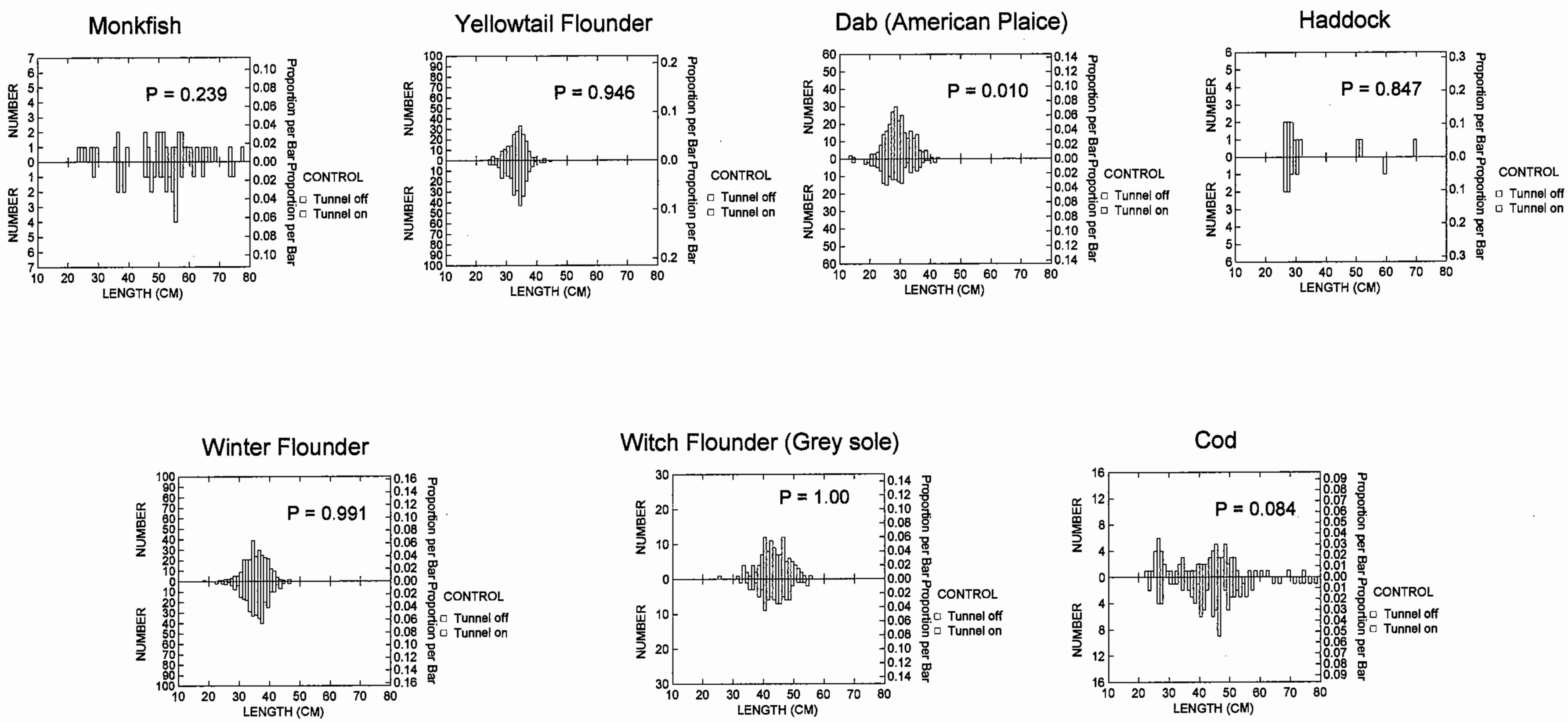


Figure 10. LFDs comparing presence and absence of black tunnel in the fall by the Christopher Andrew for sq mesh windows

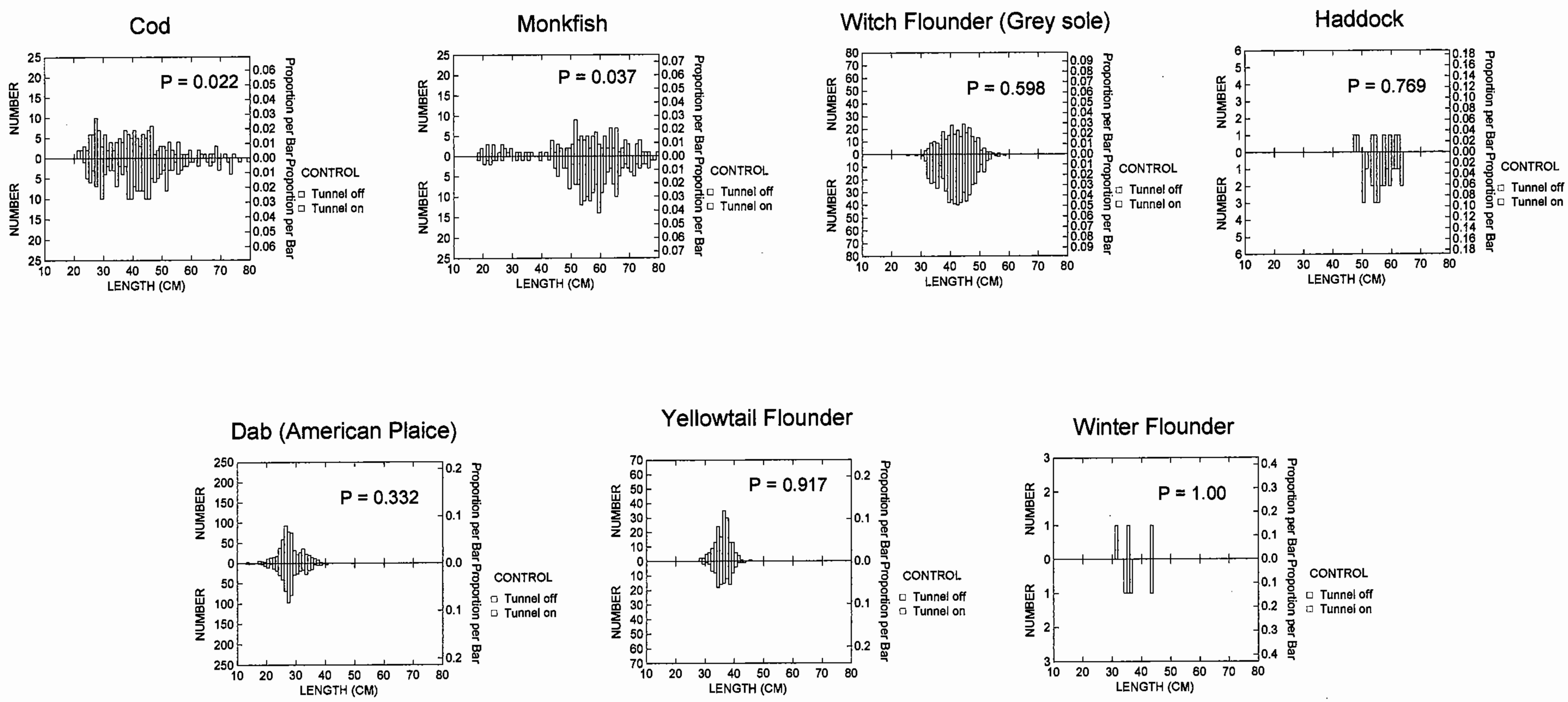


Figure 10. LFDs comparing presence and absence of black tunnel in the fall by the North Star for sq mesh windows

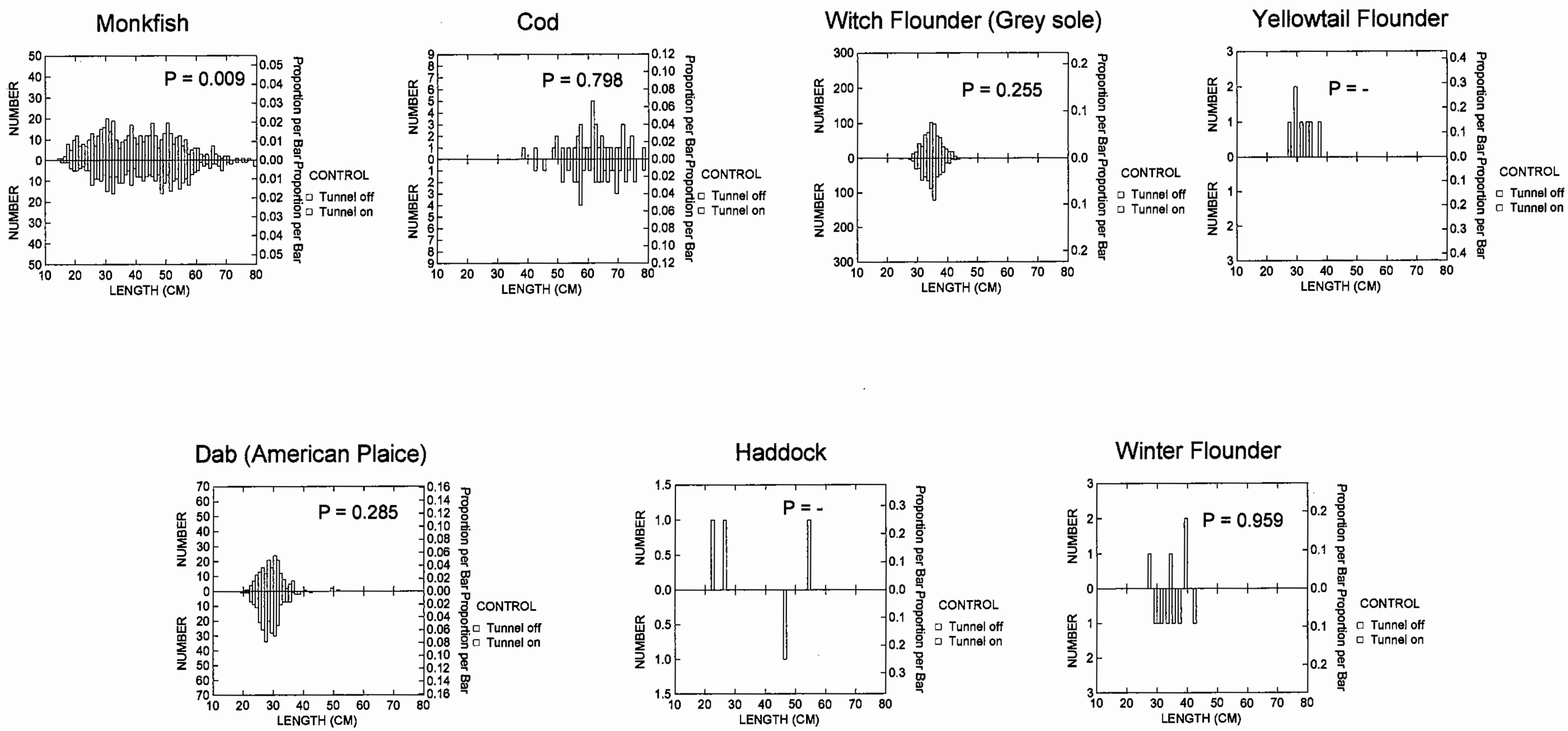


Figure 10. LFDs comparing presence and absence of black tunnel in the fall by the North Star for hex mesh windows

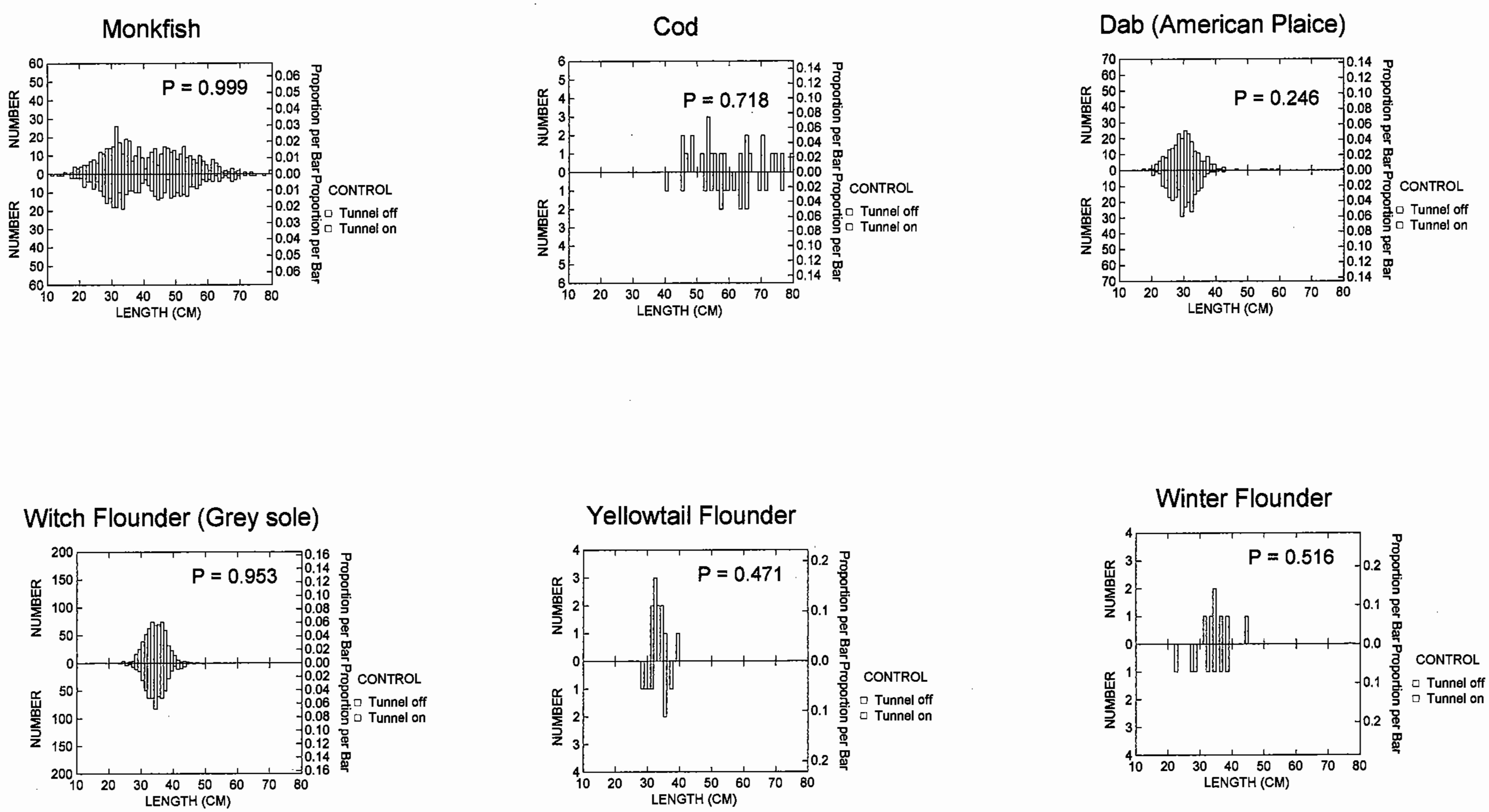


Figure 10. LFDs comparing presence and absence of black tunnel for all hauls completed in the fall by hex mesh windows

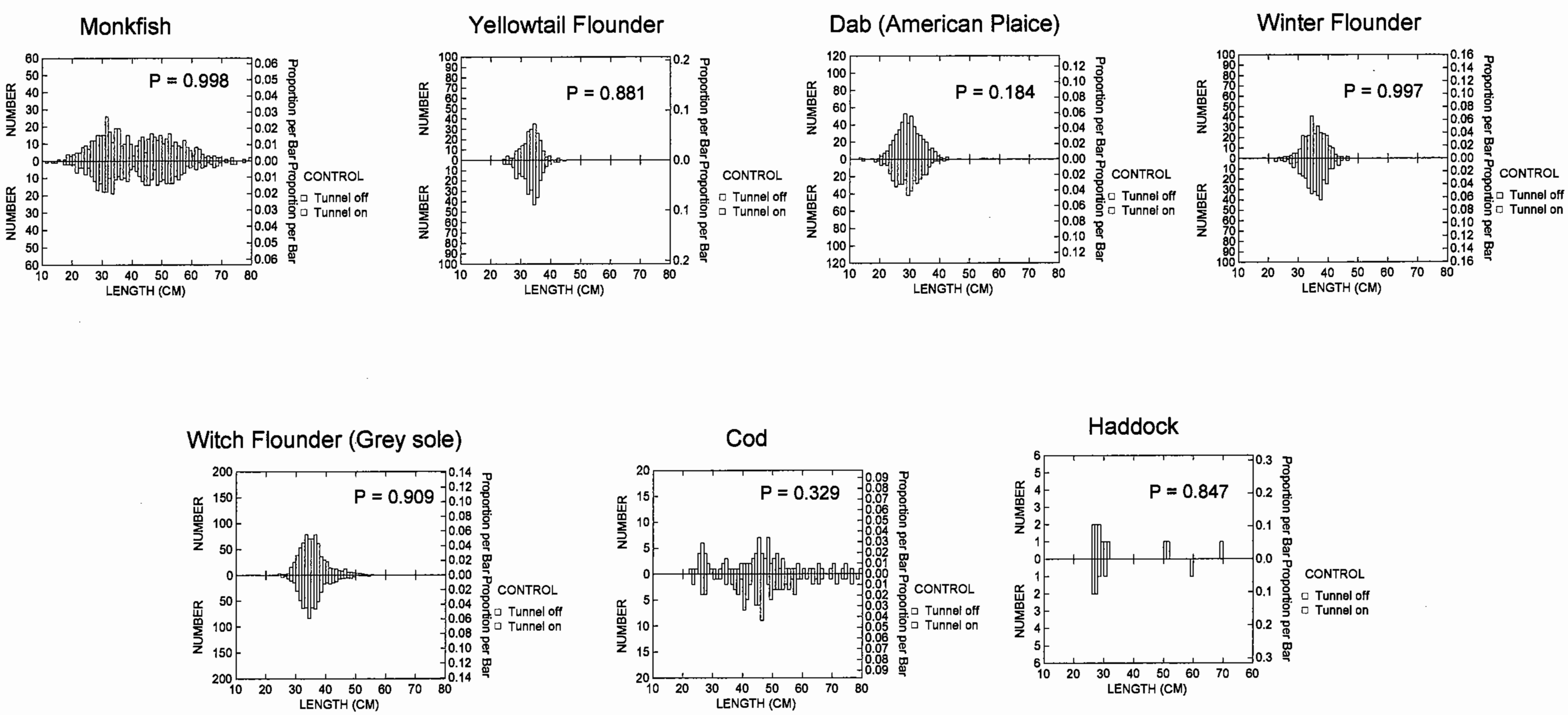


Figure 10. LFDs comparing presence and absence of black tunnel for all hauls completed in the fall by sq mesh windows

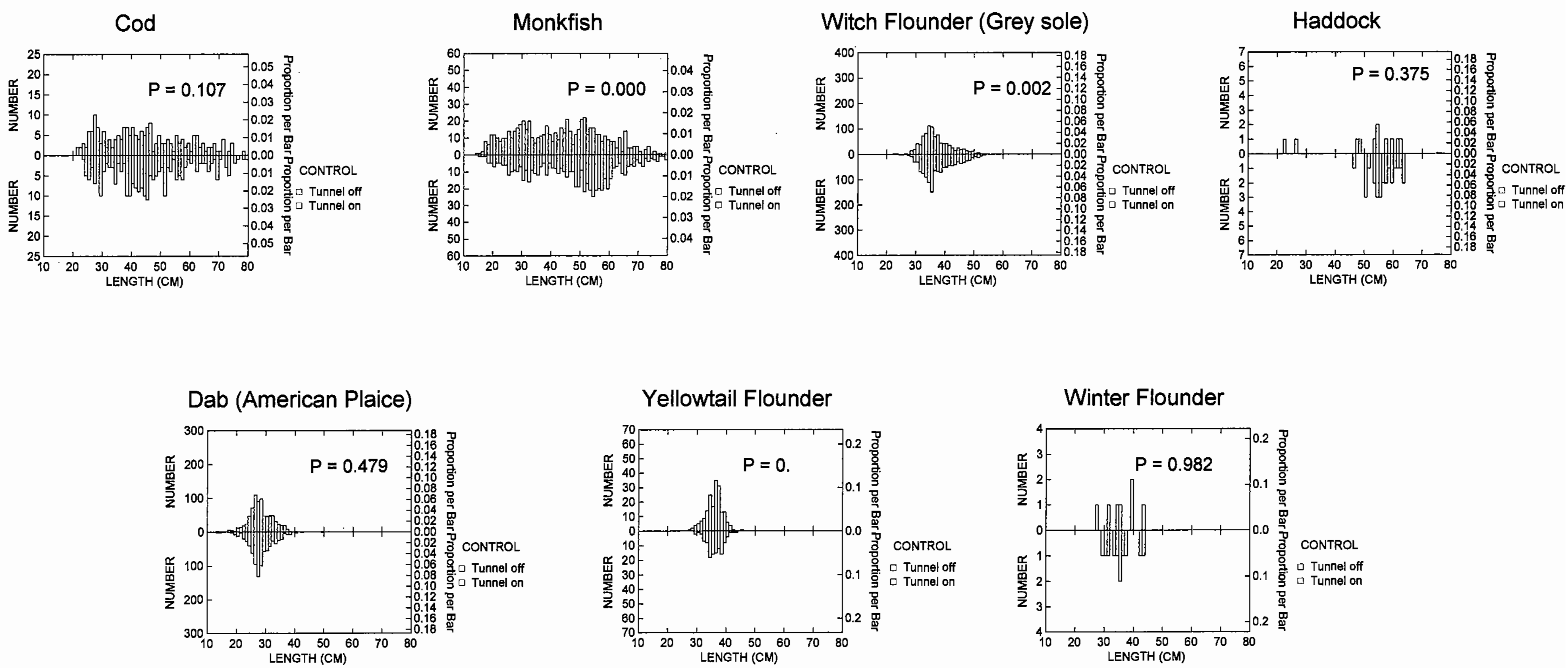


Figure 10. LFDs comparing presence and absence of black tunnel for all hauls by hex mesh windows

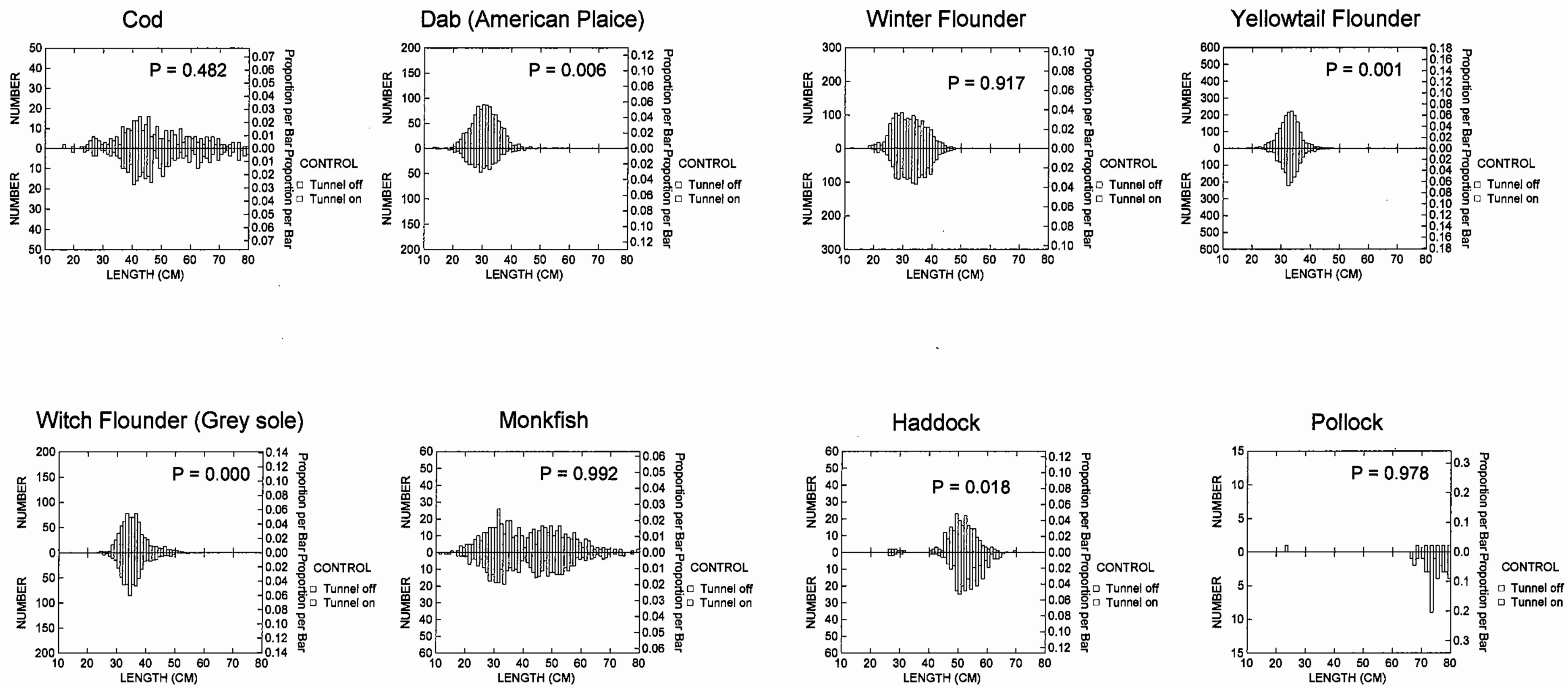


Figure 10. LFDs comparing presence and absence of black tunnel for all hauls by sq mesh windows

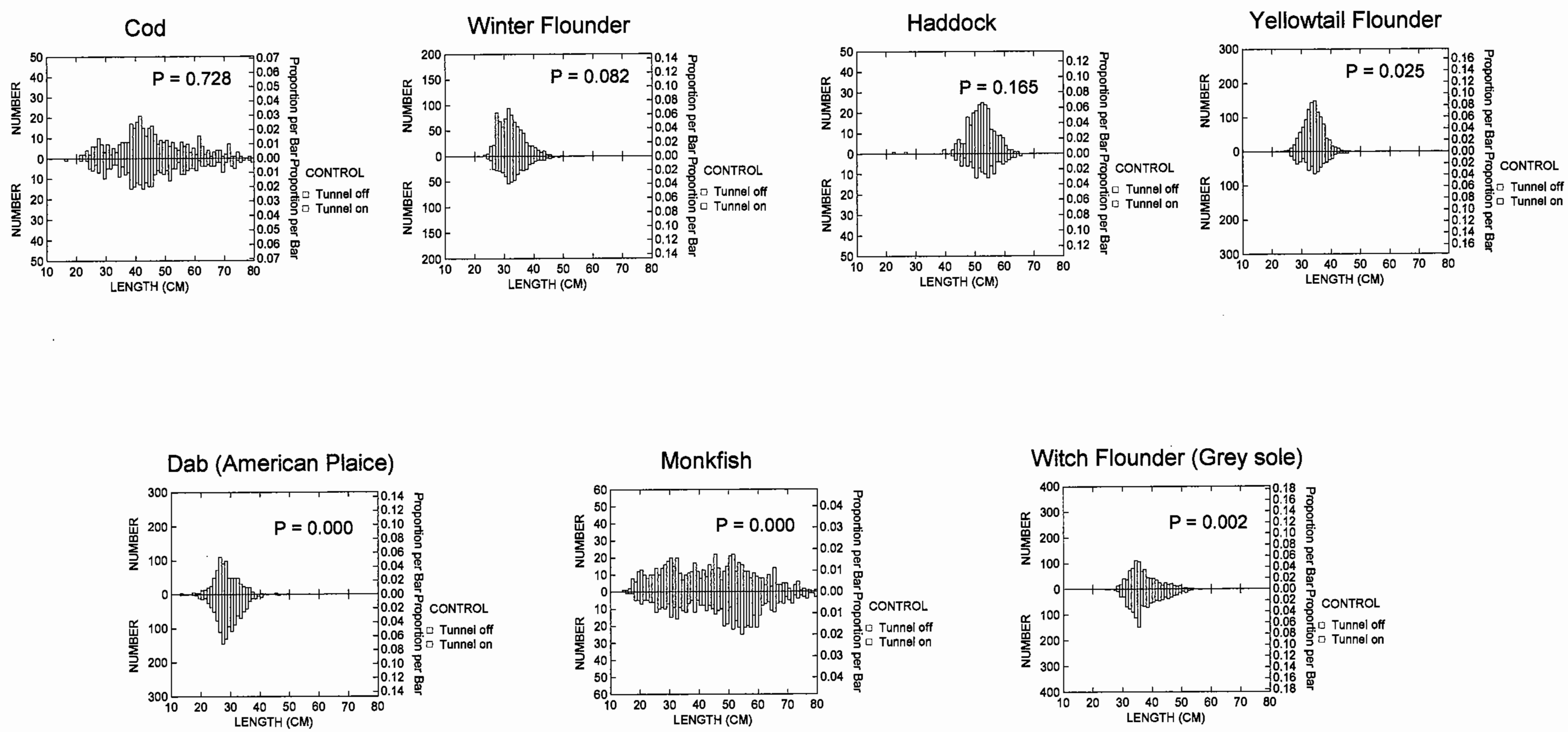
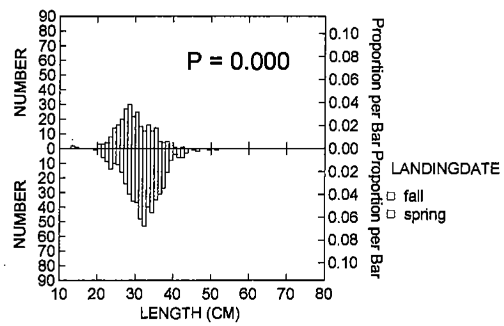


Figure11. Seasonal Comparison of Length Frequency Distributions. Length frequency distributions (LFDs) comparing populations of fish from hauls completed by the Christopher Andrew in the spring and the Christopher Andrew in the fall for each window configuration. Fish hauls caught in hauls completed by the Christopher Andrew in the fall are on the top, fish caught in hauls completed by the Christopher Andrew in the Fall are on the bottom of the mirrored figures. P value results from the two sample K-S test are listed next to each comparative figure and provide. A p value of 0.05 or less indicates significant differences in the populations of fish sampled in the fall and spring.

DAB (American Plaice)

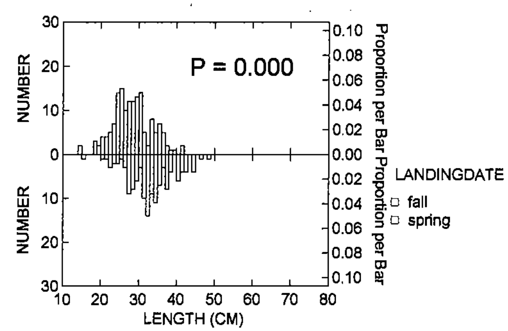
7 hex tunnel off

Seasonal Comparison



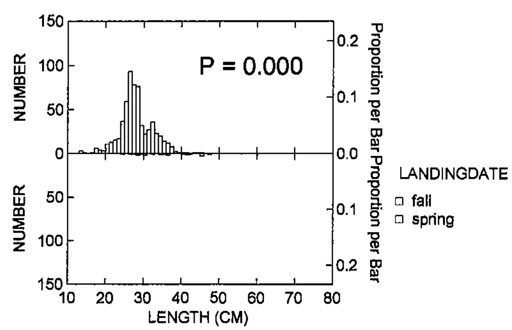
7 hex tunnel on

Seasonal Comparison



7 sq tunnel off

Seasonal Comparison



7 sq tunnel on

Seasonal Comparison

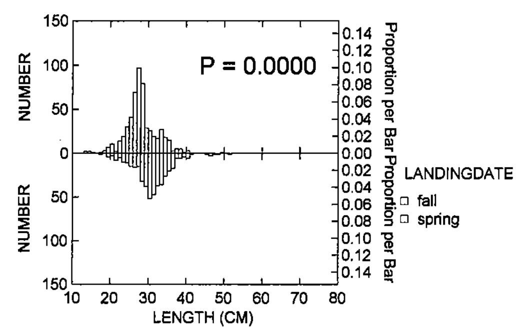
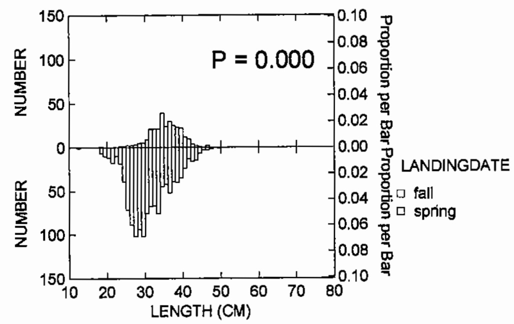
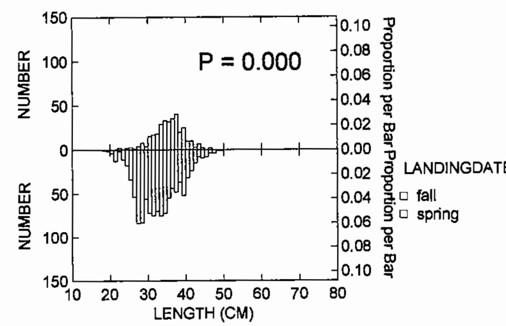


Figure 11. Seasonal Comparison of Winter Flounder (Blackback)

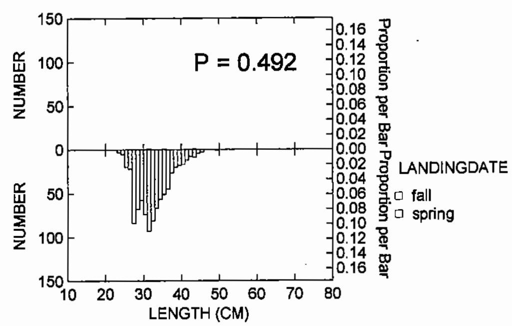
7 hex tunnel off
Seasonal Comparison



7 hex tunnel on
Seasonal Comparison



7 sq tunnel off
Seasonal Comparison



7 sq tunnel on
Seasonal Comparison

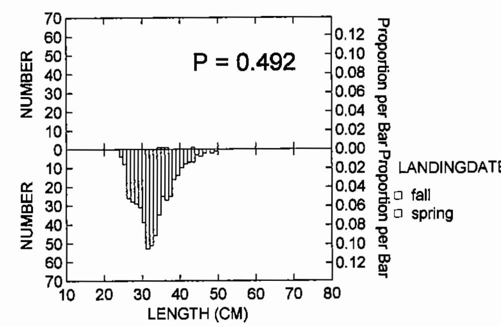


Figure 11. Seasonal comparison of Yellowtail Flounder

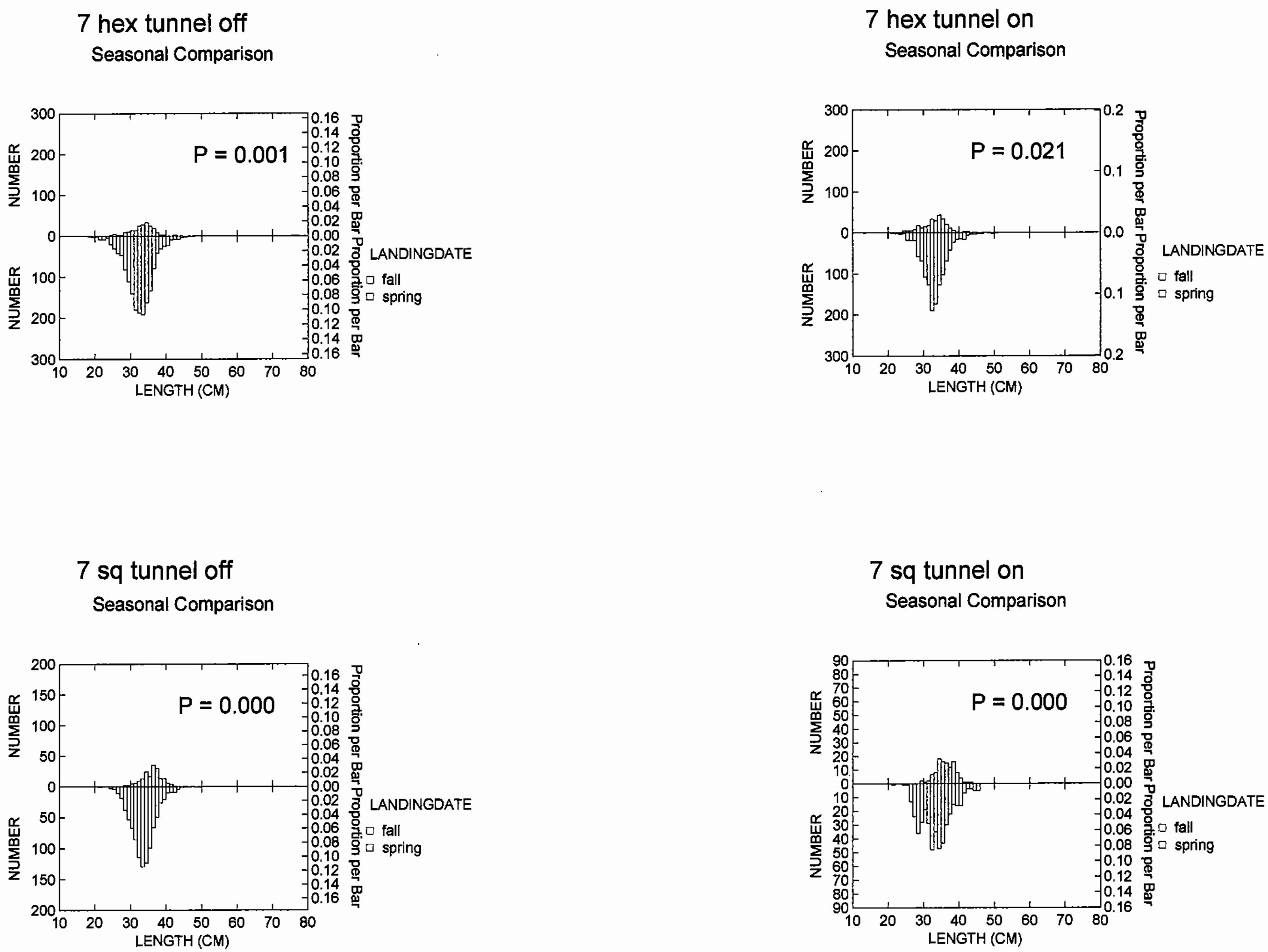


Figure 11. Seasonal comparison of Cod

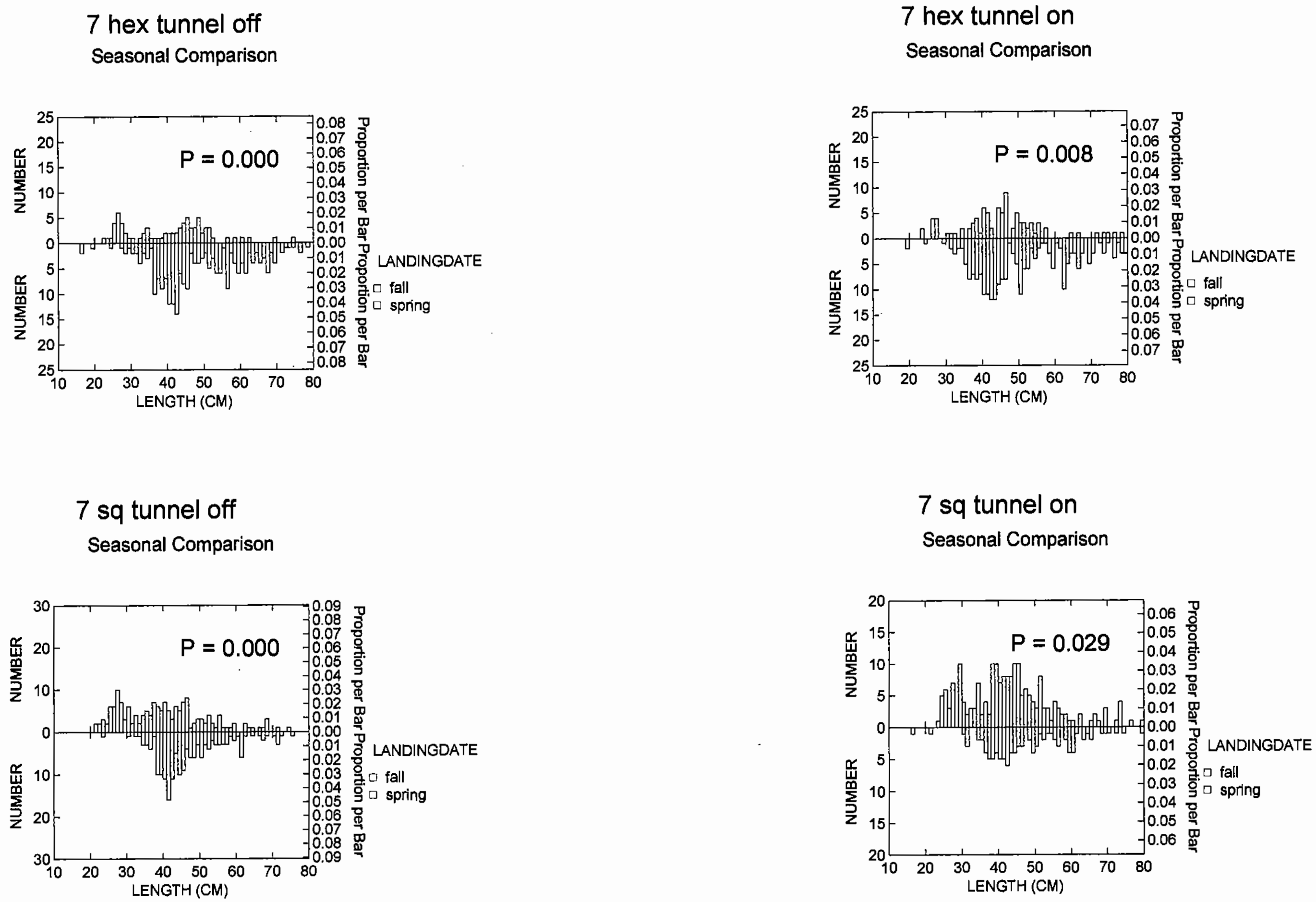
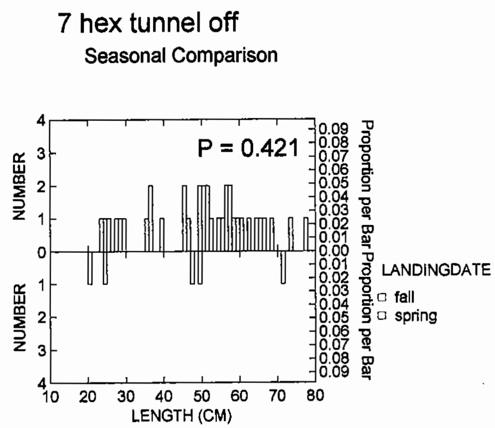
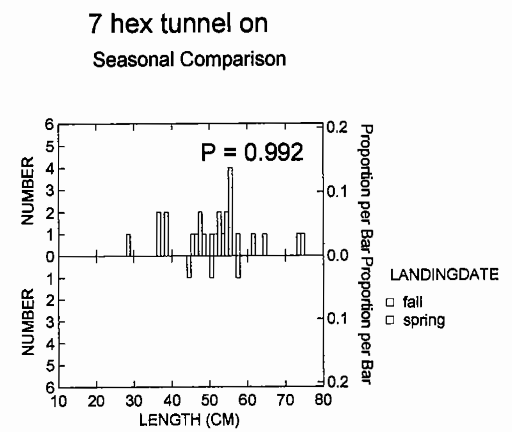
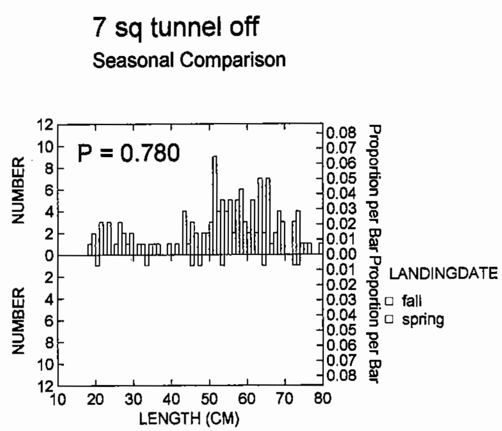


Figure 11. Seasonal comparison of Monkfish







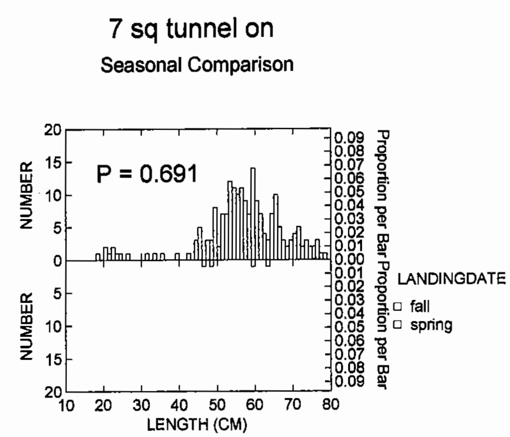
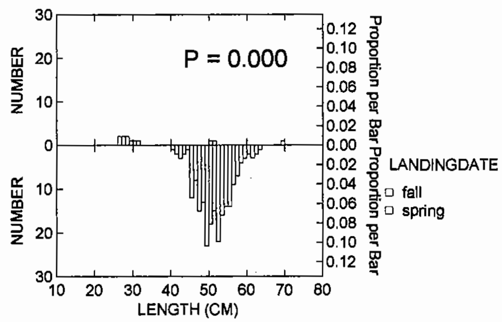


Figure 11. Seasonal comparison of Haddock

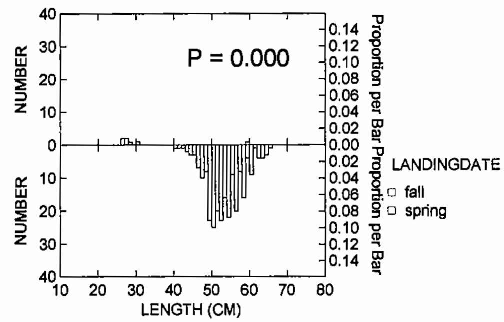
7 hex tunnel off

Seasonal Comparison



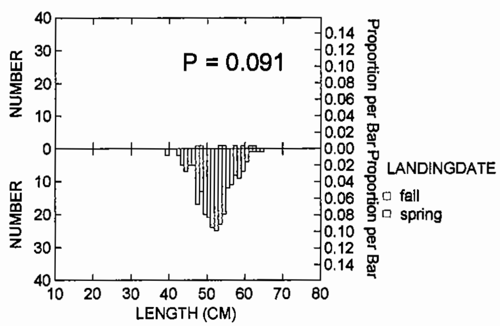
7 hex tunnel on

Seasonal Comparison



7 sq tunnel off

Seasonal Comparison



7 sq tunnel on

Seasonal Comparison

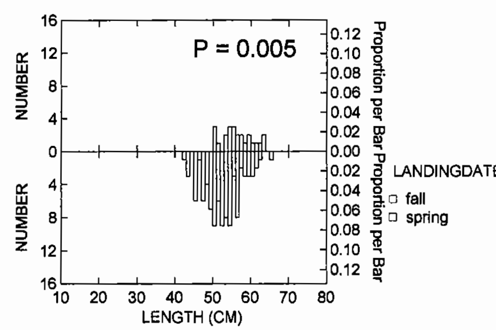
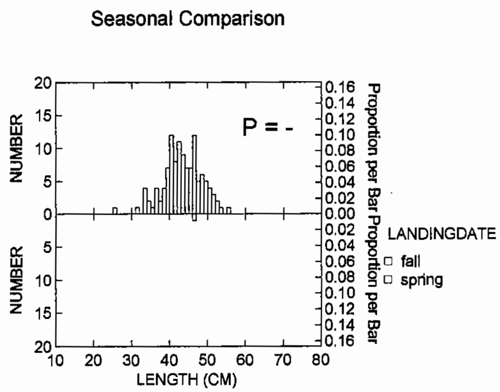
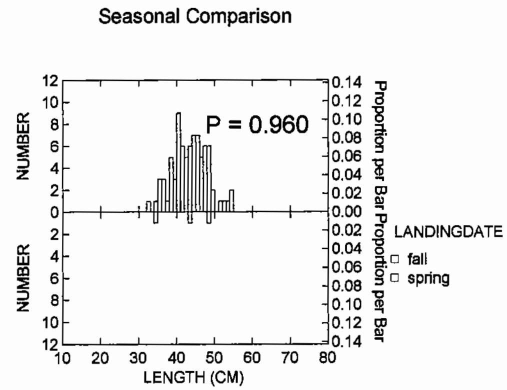


Figure 11. Seasonal comparison of Witch Flounder (Grey Sole)

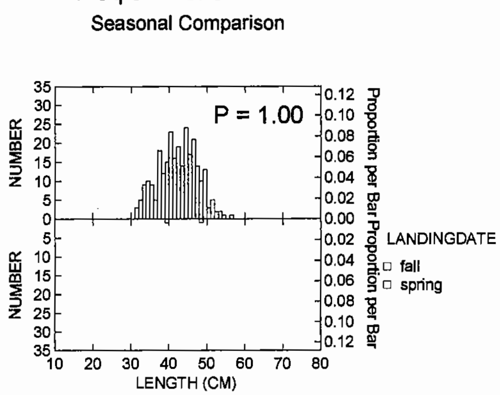
7 hex tunnel off



7 hex tunnel on



7 sq tunnel off



7 sq tunnel on

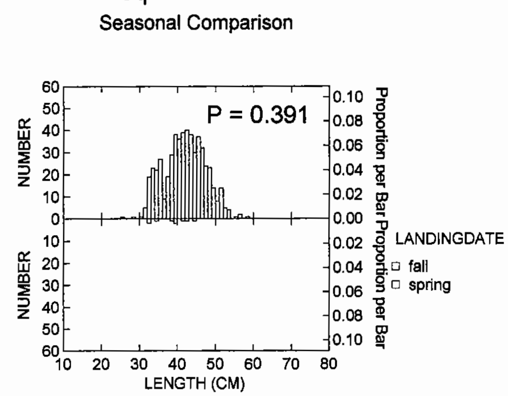
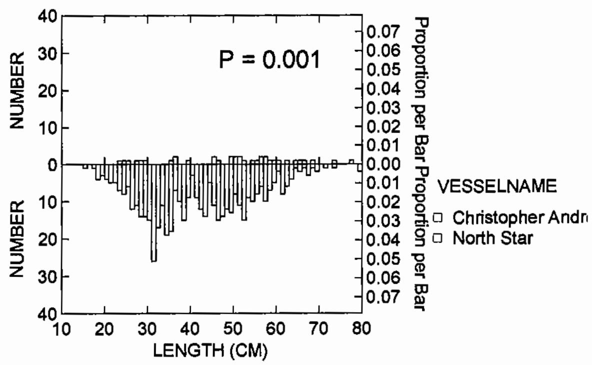


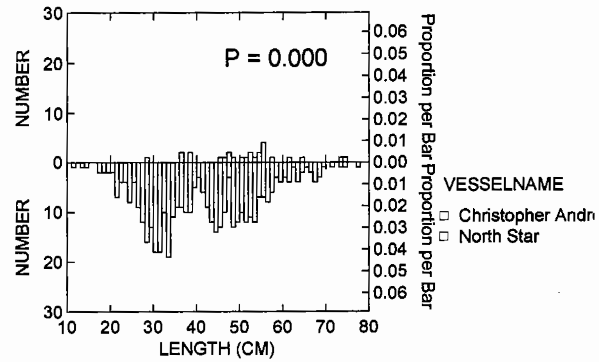
Figure12. Vessel Comparison of length frequency distributions (LFDs). Length frequency distributions (LFDs) comparing the populations of fish caught by the Christopher Andrew and the North Star in the fall by each window configuration. Fish in hauls conducted by the Christopher Andrew are on the top, fish in hauls conducted by the North Star are on the bottom of the mirrored figures. P value results from the two sample K-S test are listed next to each comparative figure. A p value of 0.05 or less indicates significant differences in the populations of fish sampled by the two vessels.

Monkfish

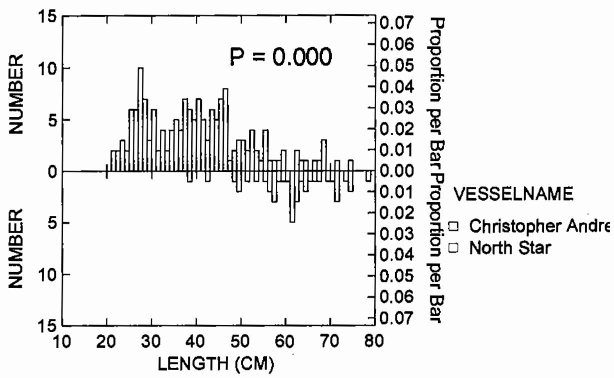
7 hex tunnel off



7 hex tunnel on



7 sq tunnel off



7 sq tunnel on

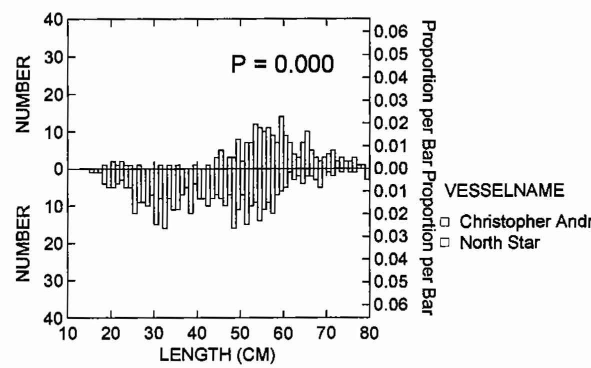


Figure 12. Vessel comparison of Yellowtail Flounder

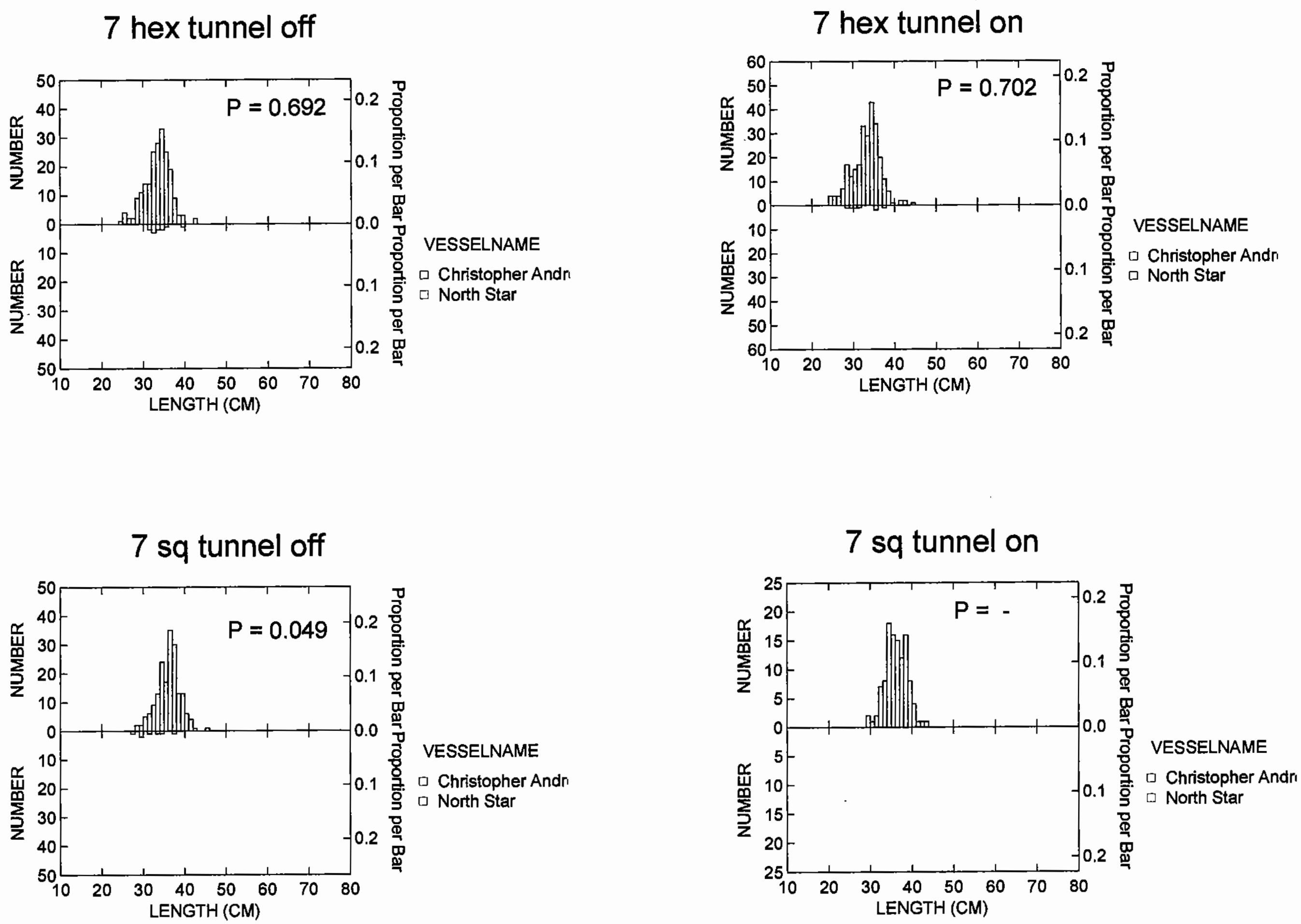


Figure 12. Vessel comparison of Dab

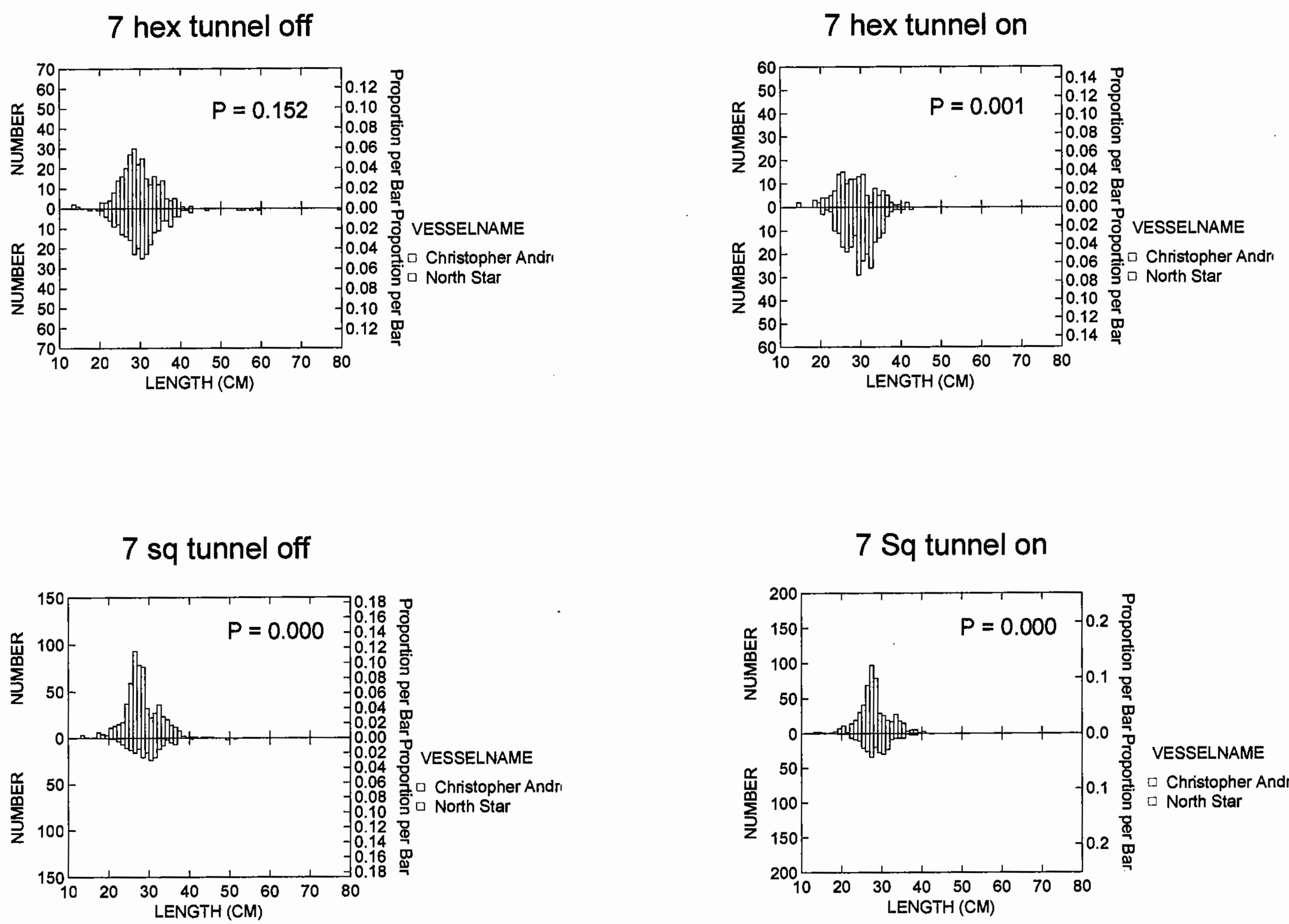


Figure 12. Vessel comparison of Witch Flounder (Grey Sole)